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ADVISORY GROUP FOR AEROSPACE RESEARCH & DEVELOPMENT

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AGARDOGRAPH 340

Aircraft Disinsection: A Guide for Military & Civilian Air Carriers

(Désinsectisation des aéronefs: Un guide à l'intention des responsables des transports aériens civils et militaires)

Author

R.A. ELLIS

This AGARDograph is sponsored by the Aerospace Medical Panel.

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North Atlantic Treaty Organization
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Aircraft Disinsections: A Guide for Military & Civilian Air Carriers

(AGARD AG-340)

Executive Summary

Aircraft disinsection can prevent the introduction of pests into a country and prevent risks to air crew health, aircraft safety, and industry. This report reviews the importance of aircraft disinsection and the potential problems associated with its use. It summarises the information that was obtained from various officials involved in the regulation of introduced pests, pesticide registration, and safe pesticide use. It also provides practical information on aircraft disinsection, obtained through numerous meetings and correspondence with researchers, private companies involved in aircraft disinsection, air force personnel, and representatives of civilian international air carriers. The end-result was the development of a model standard operating procedure for disinsection of aircraft that coud be used by the Air Forces and air Carriers of NATO countries.

Désinsectisation des aéronefs: Un guide à l'intention des responsables des transports aériens civils et militaires

(AGARD AG-340)

Synthèse

La désinsectisation des avions peut prévenir l'introduction d'insectes nuisibles dans un pays, en évitant des risques pour la santé des équipages, pour la sécurité de l'aéronef et pour l'industrie. Ce rapport examine l'importance de la désinsectisation des avions, ainsi que les problèmes potentiels associés à son application. Il résume les informations obtenues de différents officiels responsables de la règlementation des insectes nuisibles introduits, de l'inscription des pesticides et de leur utilisation en toute sécurité. Il fournit également des informations d'ordre pratique sur la désinsectisation des avions, obtenues par le biais de nombreuses réunions et de la correspondance avec des chercheurs, des entreprises travaillant dans le domaine, des personnels des forces aériennes civiles. Le résultat final de ces travaux a été le développement de consignes d'utilisation standard pour la désinsectisation des aéronefs, susceptibles d'être adoptées par les forces aériennes et les compagnies aériennes des pays membres de l'OTAN.

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Preface

With increasing numbers of humanitarian and food aid programs being carried out by NATO Air Forces in support of U.N. missions in recent years, there has been an increase in the number of incidents involving pests found aboard returning aircraft. With these occurrences, there also has been a recognition that aircraft disinsection policies and procedures need be updated to reflect the availability of more modern methods and materials and changing legislation. This review of aircraft disinsection, commissioned by the Canadian Air Force, was begun in late-1993 and ended in early-1995.

The review looked at existing national and international legislation, regulations, and recommendations and at current technologies used by several other air forces and international air carriers in an attempt to develop policies and procedures that could be incorporated into a new administrative order on aircraft disinsection for use by the Canadian Air Force and other air carriers.

The review and resultant administrative order recognized both military and public concerns over the use of pesticides in aircraft and attempted to develop an administrative order based on sound integrated pest management principles, materials and methods. The administrative order emphasizes the importance of pest monitoring and good maintenance practices in preventing pest problems aboard military aircraft and the importation of pests.

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INTRODUCTION

To prevent risks to air crew health, aircraft safety, and industry, Canada's Department of National Defence (DND) has recently reviewed the potential problems associated with aircraft disinsection. Various directives for air crew, maintenance personnel, and preventive medicine technicians to follow have been developed and updated periodically. This aircraft disinsection review is part of the latest effort to revise DND's administrative orders on aircraft disinsection and could be a model for other military and civilian air carriers.

Part A reviews and reports on legislation, regulations, and recommendations dealing with aircraft disinsection in Canada and other countries. It summarises information gathered from various officials involved in the regulation of introduced pests, pesticide registration, and safe pesticide use.

Part B reviews aircraft disinsection technology, based on the gathering and analysis of up-to-date information from researchers, from air force personnel, and from representatives of civilian air carriers who are faced with a similar requirement.

Part C is the development of a current, standard operating procedure for disinsection of Canadian Air Force aircraft in the form of an Air Command Administrative Order. It may serve as a model for other air forces and civilian airlines.

PART A. LEGISLATION, REGULATIONS, AND RECOMMENDATIONS

1. Introduction

1.1 Need for Aircraft Disinsection

All operators of aircraft fleets realize the importance of protecting air crew and aircraft from injurious pests that might affect health or aircraft safety. They also recognize the need to protect home industry, including agriculture and forestry, from introduced pests that might become established in their country and serve as vectors of disease or damage their forests or affect their agricultural production.

Often, transport aircraft, involved in humanitarian and food aid programs in developing countries, stand off on the tarmac of relatively primitive airports at night for fuel, maintenance, and loading. Like a beacon, the well-lit transport aircraft acts as a giant light trap to the local insect fauna. Judging by the remarks of some air crews, the number of insects flying in the open, rear door can sometimes be high enough to be annoying.

If there is suitable food on board for these

insects, they may settle down to feed and build up their on-board populations. Grain pests may feed on spilled grain or beans. Biting flies may feed on crew-members' blood. Even if there is no suitable food on board the aircraft for those particular insects involved, they may lay their eggs on the interior walls, in nooks and crevices. Some insect allies (e.g., venomous spiders) pose a more acute threat because of their reclusive habits and painful bites.

In recent years, there has been a significant increase in the number of Canadian Air Force flying operations around the world, involving food aid and peace-keeping activities and the use of fixed- and rotary-winged transport aircraft. Coincident with these humanitarian programs, there have been numerous instances where aircraft have been infested with various pests.

The operations have included military transport, helicopter, and fighter aircraft and civilian aircraft under contract to NATO or the United Nations. In many cases, the pests involved have been structural (i.e., those occurring in and around man-made structures, including buildings, ships, and aircraft) and agricultural insect pests (61). The aircraft most commonly infested is the Lockheed CC-130 Hercules, used mainly for troop, equipment, food, and material transport but sometimes for command and control, electronic warfare, maritime patrol, reconnaissance, search and rescue, tanker, and special operations.

Typically, the maintenance crews for the deployed aircraft need to carry a wide variety of tools, equipment, and spare parts. At the base of operations, this paraphernalia may be stored on the ground or in poorly-maintained buildings. Invariably, over time, assorted snails, spiders, and insects will attempt to use the less-frequently disturbed items as their home. If, after many months, this material is simply loaded back on the aircraft for the flight home, without a thorough inspection and cleaning, the chances are good that it will carry many potential pests to its country of origin.

Obviously, something needs to be done to prevent this from happening or to remedy the problem after it occurs (62). If nothing is done, many different kinds of pests could become serious problems and each pest could be an expensive, embarrassing, and possibly dangerous issue for the air fleet involved.

1.2 Objectives of Current Study

DND contracted with the author in late-1993 to review and report on (a) existing legislation dealing with aircraft disinsection, (b) methods and materials used by other military and civilian organizations carrying out aircraft disinsection, and (c) to draft an administrative order on aircraft disinsection for use by Canadian Air Force personnel.

2. Aircraft Disinsection

Aircraft disinsection, in its strict sense, is the control of insect pests that are present on aircraft to prevent harm to air crew, passengers, and aircraft and to prevent the introduction of exotic pests to those countries still free of them. Some workers have used this technical term in a much broader sense. They may include the control of

insects and other pests (e.g., viruses, bacteria, fungi, amphibians, snakes, birds, and mammals) in and around aircraft, air cargo, aircraft garbage, air maintenance stores, and airports. In this report, the stricter definition is used unless noted otherwise.

3. Importance of Aircraft Disinsection

The need for aircraft disinsection was recognized in the early years of commercial flight by researchers such as Sasser (80), Griffitts and Griffitts (29), Mackie and Crabtree (60), and others. In the U.S.A., one of the leaders in aircraft disinsection research, Dr. W. N. Sullivan, wrote 'the development of great intercontinental transportation systems has often proceeded without an awareness of the need or the will for quarantine action to prevent the pollution of man's environment to his disadvantage by the introduction of foreign insect vectors of disease and agricultural pests harmful to man, his crops, fibres, and animals. Unless rectified, this problem will become acute as more and more food is needed to feed the ever growing world population' (93).

Aircraft are major distributors of insect stowaways because of their number and speed. Almost 3,000 species belonging to 293 families and most of the orders of insects, many of them alive, have been intercepted inside aircraft. Although the precautions now taken to disinsect airplanes arriving from areas of pest risk do reduce introductions of economically important air-borne insects, the interception list is still too long.

Adult insects travel almost exclusively within the fuselage. The exterior surfaces and wheel housings are of lesser importance as carriers. Lights inside parked aircraft attract insects just as they do elsewhere and often are responsible for hundreds of insects finding their way in through open doors, hatches, and windows. Fortunately, it is relatively easy to eliminate insects aboard aircraft by thorough cleaning and by properly applied combinations of aerosol and residual insecticidal sprays. A minor problem has been posed by the egg masses of several species of moths found on outside surfaces. Possibly the moths, as night fliers, were attracted to the bright exteriors of illuminated aircraft (66). Frequently such eggs are still alive when found. Even freshly-hatched caterpillars have been found crawling about on the exterior surfaces of parked, egg-infested aircraft.

Pests that get aboard aircraft can be a serious problem *in situ*. They can cause damage to an aircraft. Wandering insects can make sensitive electronic equipment behave erratically. The corrosive body fluids of a defecating or rotting insect can damage a flight computer. A dead insect can jam an electrical contact. A flying or crawling insect in the cockpit can distract crew at critical times. An insect pest can also cause panic in flight. An experience with an angry wasp during take-off is something no pilot would want to experience.

Mosquito-borne disease is still common in many countries. Infected mosquitoes could easily enter a parked aircraft and spread a disease such as malaria or yellow fever among crew and passengers enroute. When an infested aircraft returns to its home country, the same pests can become esta-

blished and spread within the country, posing a risk to people, property, forests, and agriculture.

A military deployment can quickly frustrate the efforts of quarantine officials. When expediency rules, the regulatory controls may fail. Canadians are fortunate that the hazards to our health and to our agriculture and forestry industries that are presented by foreign insects are fully appreciated by the DND. The Canadian Air Force cooperates fully with federal human, plant and animal health officials. It is hoped that these guidelines will promote cooperation between other air carriers and their national agricultural agencies.

3.1 Impact of Pests on Health

Pests in aircraft may pose a risk to the health of air crew, passengers, military air bases, airport personnel, and people living in the vicinity of bases and airports.

3.1.1 Disease Transmission

The World Health Organization (WHO), primarily concerned with human health, has traditionally led efforts to develop practical and standard methods of aircraft disinsection. It recognizes the risks that are associated with disease vectors aboard an aircraft and with introducing vectors of disease to new countries where they may flourish and spread disease.

Similarly, the airline industry, the regulatory agencies, and the transportation leaders of some countries (e.g., port authorities, plant and animal health officials, quarantine officials, and the maintenance and health officials of certain airlines and air forces of Australia, Canada, New Zealand, U.K., and U.S.A.) have been international supporters of WHO recommendations and have developed enhanced equipment, methods, and materials for this practice.

Many disease vectors have been transported to new countries via aircraft, ships, and land vehicles. Some examples include *Aedes aegypti*, vector of Yellow fever, *Aedes albopictus*, vector of dengue, *Anopheles subpictus*, vector of malaria, and *Aedes togoi*, vector of Japanese B encephalitis (2, 76, 78). Hughes (38) observed more than 20,000 mosquitoes (plus many other insects) aboard aircraft arriving in the U.S.A. Of the 92 species identified, 51 were species new to the U.S.A.

Both sexes of several mosquito species have been collected in some studies, showing the risk of introductions to be very high in some cases.

Several cases of malaria have occurred amongst people, living or working near international airports where malaria is not endemic and not having travelled to malarial countries. Such cases have been reported since the mid-1970's in France, the United Kingdom, the Netherlands, Belgium, Italy, Singapore, Spain, and Switzerland (2, 40, 51, 52, 67, 103).

Reports of new cases point out that aircraft are bringing in vectors and that some of these vectors can become established and spread disease. Several researchers (46, 47) have indicated that these cases of vector-borne disease illustrate the need for vector control in and around international airports routinely receiving flights from disease-prone countries.

With the resurgence of these and other diseases in many developing and some developed countries, governments, the transportation industry, and armed forces around the world have paid more attention to the subject of aircraft disinsection. The resurgence has been caused by the disintegration of disease control programs in many developing countries, the increasing number of pests that have become resistance to the cheaper, older, and more commonly-used pesticides (70), the increasing flow of refugees from war-torn countries, and the increased amount of traffic between countries, both in trade and tourism.

Because of this resurgence in malaria and yellow fever vectors, WHO issued a list of countries from which departing aircraft should carry out disinsection procedures:

- Afghanistan
- South Africa
- Angola
- Bangladesh
- Benin
- Bhutan
- Birmanie
- Botswana
- Brazil
- Brunei Darussalam
- Burkina Faso
- Burundi
- Cameroon
- China (Shanghai)
- Colombia
- Comoros
- Congo
- Ivory Coast
- Djibouti
- Ethiopia
- Gabon
- Gambia
- Ghana
- Guinea
- Guinea Bissau
- Equatorial Guinea
- Guyana
- French Guiana
- Solomon Islands
- India
- Indonesia
- Cambodia
- Kenya
- Liberia
- Madagascar
- Malawi
- Mali
- Mozambique
- Namibia
- Nepal
- Niger
- Nigeria
- Uganda
- Pakistan
- Panama
- Papua New Guinea
- Central African Rep.
- Laos
- Rwanda
- Sao T.-and-Principe
- Senegal
- Sierra Leone
- Somalia
- Sudan
- Sri Lanka
- Surinam
- Swaziland
- Tanzania
- Chad
- Thailand
- Togo
- Vanuatu
- Viet Nam
- Zaire
- Zambia
- Zimbabwe

In many developed countries, the movement of disease vectors and disease reservoirs has been too great for the number of quarantine and immigration officials that must deal with the problem, especially during long periods of worldwide economic decline. Yet, this spread must be managed because, if it is not, the costs involved in reactive measures are too high. The many millions of dollars spent in trying to eradicate a single introduced insect pest or disease could be better spent in prevention.

When all countries agree to abide by an international standard for aircraft disinsection and they require organizations operating from within their boundaries to abide by this standard, the spread of disease organisms and their vectors will be kept down to a trickle. However, it will require more than agreements to make this happen.

Currently, some of the large organizations involved in the aerial transportation industry in those countries that profess to support WHO recommendations have policies that agree completely with the WHO standards. But, they may not enforce the policies amongst their staff.

An aircraft disinsection policy and procedures may be impressive only on paper.

In the field, where it counts, disinsection procedures may be unassigned, poorly executed, done sporadically, or skipped entirely, without management being aware of the deficiencies. Often, the key problem has been that the individual or individuals directly responsible for aircraft disinsection has had no serious training in its health importance or in its technical execution. Management typically blames this deficiency on poor communications or record-keeping. Staff typically state that they are too busy with more important matters and have insufficient time to devote to aircraft disinsection or that they are not provided with the resources necessary to carry out the work. Clearly, these problems must be solved to minimize the risks of accidental introductions of destructive pests and diseases.

3.1.2 Aircraft Damage

Rodents, including mice and rats, are uncommon hitchhikers on aircraft. Most major airports, utilizing sky-walks (also called 'aerobridges' or 'jet-ways') for passengers and strict warehousing standards, offer little opportunity for rodents to get aboard aircraft. But, occasionally, they do get onto aircraft, usually in goods or containers but occasionally via wheel wells or stairways.

A rodent aboard an aircraft poses a serious risk to the proper operation of the aircraft (2). Rodents have the nasty habit of chewing on wire coatings and coverings, partly to sharpen their teeth, partly to collect materials for nesting, and partly out of boredom. Regardless of the reason for the damage, a responsible airline will ground that aircraft until the rodents have been destroyed and all of the electrical and control systems have been inspected for air worthiness.

3.2 Impact on Agricultural and Forestry Industries

Aircraft returning from abroad and carrying pests present a risk to the home economy, especially through the agricultural and forestry industries.

3.2.1 Risk of Introduction of Agricultural Pests

Insects and other pests can easily survive the few hours involved in most international flights (57). Even during the early years of flight, mosquitoes were reported to survive up to 80 hours of flight at altitudes of 14,000 feet (45). A pest, introduced into a country by an aircraft carrying contaminated equipment or goods, can devastate a local industry.

In Canada, where two of the main industries are agriculture and forestry, the country is especially at risk when it comes to insects and diseases affecting plants and animals produced for domestic consumption or foreign export. The fact that most airports are now located in semi-rural areas in order to escape noise abatement legislation, often adjacent to farming or forestry operations, increases the risks of a plant or an animal pest becoming established. The risks are not simply hypothetical. Based on the experiences of other countries (e.g., U.S.A., Australia, and New Zealand), exotic pests are introduced by all modes of transportation, including aircraft.

Food pests (both insects and diseases) may infest spilled grains. Some food pests are vectors of viruses, bacteria, fungi, protozoa, and helminths. Nematodes, fungi, bacteria, and viruses that may be harmful to plants and animals may be present in soil or partially-consumed grains.

The published literature includes many reports of insects detected aboard arriving aircraft (e.g., 16, 19, 26, 37, 46, 47, 50, 53, 63, 69, 78). The average number of insects recovered per plane ranges from 1-20. The average percentage of infested aircraft ranges from 10-100%. Although almost every type of insect has been recovered, the most common invaders are flies.

Surveys have also been conducted of pests introduced into areas, usually through aircraft (10, 11, 12).

3.2.2 Potential Impact on Agricultural Industry

When an aircraft brings an agricultural insect pest into a country that up to that point was free of that pest, it may be a potential catastrophe. If the environmental conditions are such that the insect can survive in its new country, feeding upon a major agricultural commodity, it may spread throughout the area swiftly. Without its normal range of natural enemies, the pest populations may reach astronomical numbers and devastate the crops affected.

An example of such a pest is the Russian wheat aphid. Although this insect has dispersed across oceans and continents, borne on wind currents, not aircraft, it illustrates the damage that can be done by one species of insect when it is no longer kept in check by its natural enemies. Millions of acres of wheat in most wheat-growing countries of the world have been affected. Several countries have had to spend hundreds of millions of dollars to develop new materials and methods to deal with the management of this one exotic pest.

3.2.3 Potential Impact on Forestry Industry

The key concern is the introduction of wood-boring insects in wooden packing crates, wooden pallets, and manufactured wooden items. Larvae might be present, complete their development, and emerge as adults to mate and lay their eggs in nearby trees, logs, and/or lumber products.

Other tree pests may be transported as resting eggs or pupae, attached to various exterior portions of the aircraft and in and on all manner of cargo. Because the forestry industry is so important to the economy of so many countries, the introduction of a serious forest insect pest by aircraft could be catastrophic.

4. Importance of Quarantine Regulations

Politics, legislation and quarantine influence pest management from a national and international perspective. Government policy can directly affect pest management, through government funding of research and extension, or it can indirectly affect it, by imposing constraints on agricultural production, pricing and marketing. Government policies for overseas aid can also have important implications for programmes in pest management.

Acts and regulations passed by government

may control the availability of products for use in pest management. Regulations governing quarantine procedures are another area where legislation plays an important role. Quarantine is a control technique in its own right because quarantine procedures can be used as a means of preventing the spread of important insect pests across international boundaries.

Increasing levels of international trade and transport present an increased risk of pest introductions. Species that could only disperse over short distances by natural means can now be speedily transported from one country to another by aircraft. The threat of the accidental introduction of a major pest species has encouraged governments to take steps to reduce the likelihood of such introductions. Introductions can be prevented through the enforcement of quarantine regulations.

Quarantine regulations generally reduce the chances of a pest being introduced on imported commodities. They specify which commodities can and cannot be imported. They also specify under what conditions certain imported goods can be brought into a country. The conditions may include the need for permits, inspections, treatments, and waiting periods.

The goods may be plants, animals, plant parts or materials, meat products, agricultural commodities, soil, containers, packing material, plant growing media, baggage or mail or any other article that could harbour a pest species Such pests such as viruses, fungi, and bacteria, which may be present in or on plants, animals, and soil, are particularly difficult to find and exclude. Insect pests, although potentially a very serious problem, seem to be much less of a concern for some regulatory officials, perhaps reflecting their education or interests.

4.1 Types of Pests Introduced

Although thousands of pests are named in the quarantine regulations in different countries, several hundreds are insects and mites. The 10 most frequently cited pests are listed below. Although major pests, none of these organisms is likely to be moved by natural means between regions, except perhaps for species such as potato beetles and fruit flies which can be dispersed on wind currents.

- *Quadraspidiotus perniciosus* (San José scale).
- *Leptinotarsa decemlineata* (Colorado potato beetle).
- *Ceratitis capitata* (Mediterranean fruit fly).
- *Rhagoletis pomonella* (Apple maggot).
- *Dacus dorsalis* (Oriental fruit fly).
- *Popillia japonica* (Japanese beetle).
- *Anthonomus grandis grandis* (Boll weevil).
- *Anastrepha ludens* (Mexican fruit fly).
- *Rhagoletis cerasi* (Cherry maggot).
- *Phthorimaea operculella* (Potato tuberworm).

Risk is the key element considered in the development of plant quarantine regulations. The risk is the actual or perceived threat of pests of quarantine significance travelling along man-made pathways. Each pest will be placed at some point in a continuum, ranging from a very high to a very low risk, depending on the possibility of being brought in and the potential costs of controlling it should it become established in a country.

Quarantine, to prevent the introduction of a new pest species, is becoming an important facet of every developed country's agricultural policies as the exports and imports of fresh produce increase. Every effort should be made to ensure that aircraft returning from a foreign country are free of pests before they return to their home base.

5. World Health Organization Recommendations

WHO recommendations on aircraft disinsection are revised or updated periodically by an international team of expert advisors in the fields of agriculture, health, and air transportation. They are published as an annex of the International Health Regulations. The changes made reflect the availability of new equipment and safer and more effective pesticides.

WHO has been interested in aircraft disinsection, from a disease prevention point-of-view, since its inception. In 1961, the WHO Expert Committee on Insecticides reviewed the subject of aircraft disinsection (1). They recommended 'blocks-away' aerosol treatments of the aircraft cabin. The flight deck should be treated 'at a suitable time' (not specified) before occupancy by the flight crew. Cargo holds and wheel wells are to be disinsected as near to the time of departure as time permits. The insecticide used should be as or more effective than the standard formulation (see next paragraph). The 1961 review also outlined standard methods for the bioassay of candidate aerosols for aircraft disinsection and test procedures for aerosols and aerosol dispensers.

The 1969 version (revised in 1974) provided a description of the hand-operated, aerosol dispensers, the discharge rate, and the standard formulation:

Components	Percentage by Weight
Pyrethrum extract (25% pyrethrins)	1.6
DDT Technical	3.0
Xylene	7.5
Odourless petroleum distillate	2.9
Dichlorodifluoromethane	42.5
Trichlorofluoromethane	42.5

Instead of the above pyrethins-DDT mixture, the following active ingredients were considered effective alternatives: 2% Resmethrin, Bioresmethrin, Permethrin *or* 2% d-Phenothrin mixed with Freon 11 (49%), and Freon 12 (49%).

In 1985, WHO recognized that approved, 'blocks-away', aerosol disinsections were not always satisfactory because some people may be susceptible to the inhalation of components of the insecticidal aerosol and recommended the use of permethrin as a safe and effective residual spray (2).

They suggested using a spray or aerosol to apply the permethrin residual treatment monthly to carpet and other surfaces in cargo and baggage holds, cupboards, closets, toilets, and other enclosed compartments. They recommended an even

deposit of 0.5 g/m^2 of permethrin on carpets and 0.2 g/m^2 of permethrin on other interior surfaces. They also stated that 2% permethrin, in a totally freon-based aerosol, can be used to treat electrically-sensitive areas such as the flight deck of aircraft.

The 1985 version of the WHO recommendations was published in the WHO Weekly Epidemiological Record (3, 4). It was a reiteration of the recommendations made in 1974, for the insecticide formulations involved. It also formalized the 1985 recommendation noted in the above paragraph.

Whether done at 'blocks-away' or upon approach (but before disembarkation), aerosol spraying is most effective when the insects aboard the aircraft are active (47, 48): i.e., when the motors are run-up prior to take-off and when they throttled down before landing that the aircraft is subject to heavy vibration. Aerosol treatments only kill those insects that come into direct contact with the aerosol droplets. Vibrations stir up the resting insects and expose them to the aerosol droplets.

Aircraft disinsection is only one important facet of a larger pest management system. All pests and all sources of these pests must be considered part of the larger system. For example, clearing a plane of pests is pointless if, a few hours or a few days later, the plane is re-infested when pest-contaminated food materials, equipment, effects, containers, or other goods are taken aboard.

6. Approaches to Aircraft Disinsection

Different countries may have different approaches to aircraft disinsection, depending on their location, their financial resources, the importance they place on preventive medicine to protect their citizens from disease, and the value that they place on their natural resources (especially agriculture and forestry). Politics may also affect the policies that are adopted by any given country.

The philosophy and the regulatory procedures of several key countries are reviewed below. The information presented is based, in part, on discussion and correspondence with representatives from regulatory agencies in the countries involved. It is also based on technical reports and publications they may have provided. All of the representatives from industry and government that were interviewed in this study indicated that their policies and procedures relating to aircraft disinsection were currently under review.

6.1 Canadian Approach to Aircraft Disinsection

Many Acts and Regulations, at both the federal and provincial level, impact, to some degree, aircraft disinsection. Some of the key legislation is discussed below.

6.1.1 Pest Control Products Act and Regulations

Health Canada is the key government department dealing with aircraft disinsection. One division, the Pest Management Regulatory Agency, is responsible, under the Pest Control Products Act, for the registration of insecticides and other pesticides that can be used aboard aircraft.

Less than a dozen insecticide formulations have been registered for aircraft disinsection in Canada because of our relatively expensive pesticide registration system and the small market for such products. To complicate matters further, there are a host of other Acts and Regulations that impact, directly or indirectly, on how those products that have been registered can be used so as to protect the user, the bystander, and the environment.

6.1.2 Legislation, Regulations, and Directives on Safe Use of Pesticides

The Personnel Management Component of Canada's Treasury Board Manual contains a chapter on safe pesticide use. Various requirements for pesticide use include integrated pest management programs, safe work procedures, protective equipment and clothing, and the safe storage, handling, application and disposal of pesticides. All federal employees, including military personnel, must follow these strict guidelines.

6.1.3 Federal Legislation dealing with Plant and Animal Quarantine

Divisions of Agriculture and Agri-Food Canada, including Plant Health and Animal Health, are responsible, under several Acts (including the Health of Animals Act, the Plant Protection Act, the Seeds Act, and the Feeds Act) for the inspection of aircraft and commodities imported by aircraft to determine if they are infested with potentially damaging pests that might affect Canadian agriculture and forestry (including insects, seeds, and microorganisms).

Although Canadian quarantine procedures are generally good, many of our plant and animal health officials are unable to provide any informed direction to either military or civilian carriers that arrive in Canada with insects on-board. The direction given to crew is that the aircraft must be disinsected before it can be moved. Little, if any, advice is given on how that is to be properly accomplished. It appears that few Canadian quarantine officials receive rigorous training on international aircraft disinsection standards. Fortunately, the Canadian Air Force and the major civilian air carriers have developed their own disinsection policies and procedures to deal with such contingencies.

6.1.4 Provincial Legislation

Insect pest and vector control, in and around Canada's international airports, is rare unless it is carried out under the authority of an adjacent municipality whose aim is to protect its citizens from nuisance mosquitoes, breeding on airport grounds. In some cases, outdoor airport insect control is limited to occasional programs of grasshopper and earthworm control, aimed at reducing the attractiveness of airport grounds to birds feeding on these organisms and posing a threat to aircraft. The lack of disease vector control is a matter needing serious attention at some of our Canadian airports (53).

6.1.5 Disinsection by Canadian Air Carriers

Air Canada has an excellent policy and procedure on disinsection of its cargo and passenger aircraft. Their approach to pest management is strictly reactive, controlling pests only when required or reported, without any preventive measures (other

than good hygiene and cleaning practices), and it serves as a good model. It might be enhanced by regular pest monitoring and spot spraying of residual insecticides in high pest-risk areas of the galleys.

6.2 United States Approach to Aircraft Disinsection

Based on this review of U.S. federal and state regulations dealing with health and quarantine matters and aircraft disinsection, the whole issue of passenger aircraft disinsection seems to be in a state of flux. Indeed, the issue has been simmering for the past 10 to 15 years.

Questions have been asked about the value and effectiveness of aircraft disinsection compared to its potential adverse effects on passenger health and the environment. It appears that most American professionals who are associated with aviation, disease control, agriculture, and pest management view aircraft disinsection as an important tool in protecting crew, passengers, aircraft, and commodities. On the other hand, most environmentalists and some regulatory officials see it as unnecessary and potentially hazardous (see also Section 7.1 below).

6.2.1 Plant and Animal Quarantine Regulations

The regulatory agency involved in aircraft disinsection in the U.S.A. is the Plant Protection and Quarantine (PPQ) Division of the U.S. Department of Agriculture (U-SDA). It guards the U.S.A. against entry of foreign plant and animal diseases and pests and has the task of controlling, eradicating, or preventing the spread of the any foreign plant diseases or pests that become established.

U.S. federal laws enable the USDA to develop and carry out programs to eradicate, control, or prevent the spread of destructive plant pests. Programs are conducted mainly in Mexico and Central America to prevent the spread of destructive plant pests into the U.S.A. Cooperative relations have been established with Canada on program pests of mutual interest.

To protect the U.S.A. against the introduced pests, PPQ carries out the following tasks:

1. Inspects agricultural commodities at international ports of entry (e.g., fruit flies).
2. Detects pests new to the country (e.g., Asian gypsy moths).
3. Monitors and prevents the spread of introduced pests into new areas (e.g., gypsy moths; Japanese beetles).
4. Prevents the spread of dangerous, introduced insects, nematodes, and plant diseases, while they are still confined to a small area, through eradication programs.
5. Initiates emergency programs to control serious outbreaks of pests and assistance in the prevention of impending catastrophes of animal and human diseases.
6. Provides technical assistance in pest control to other agencies and to individuals in the U.S.A. and other countries.

It is in the second, third and fourth areas above that the PPQ mainly becomes involved in aircraft disinsection. Unlike a Canadian Plant Quarantine official, who may detect a pest aboard a military aircraft

and then ground the aircraft and require the eradication of the pest, the PPQ official will both detect and control the pest.

When the PPQ officials deem it necessary to spray the cabin of an aircraft with an aerosol to control, for example, Japanese beetles during June and July, the plane must remain unoccupied for at least 25 minutes before passengers and crew can board. Galleys must be sealed off before spraying begins. Outside the galley, any exposed water fountain, beverage and food preparation surface, and oxygen mask must be covered.

6.2.2 US Air Force Disinsection Policies

The policies and procedures on aircraft disinsection of the US Air Force are currently under review. Presently, aircraft disinsection by Air Force personnel is limited to the use of d-phenothrin aerosol to comply with foreign quarantine regulations. They do have the capability of applying a residual spray to their transport aircraft (e.g., C-5A Galaxy) but this procedure is on hold while their overall policy and procedures are being reviewed.

As far as prevention goes, the U.S. Department of Defense has a policy on and procedures for the cleaning of military equipment and vehicles before they are taken onto ships or aircraft for transport back to the U.S.A.. These procedures provide excellent detail on the equipment, materials, and methods used in the cleaning of such equipment and vehicles. Although vehicles are seldom transported by military aircraft, these preventive measures should be considered by military air carriers hauling major equipment.

6.3 British Approach to Aircraft Disinsection

The United Kingdom (U.K.), like many countries, is interested in maintaining aircraft disinsection, especially as a quarantine measure to prevent the introduction of exotic mosquito pests and vectors. In the mid-1980's, the U.K. introduced a selective requirement for disinsection of aircraft arriving from countries that present a potential risk of introducing *Anopheles* mosquitoes because of increasing cases of 'airport malaria'.

6.3.1 British Airways Policies and Procedures

British Airways staff submit emptied insecticide aerosol cans (used in aircraft disinsection) to the Port Health Authority upon arrival. The airline follows the WHO 'blocks-away' cabin procedure when departing certain high-risk countries. Following an announcement to passengers, the cabin crew treat the interior of passenger aircraft with d-phenothrin; a ground engineer sprays the hold just before closing the cargo door for departure. Although some complaints are lodged (e.g., irritation of eyes of some people wearing contact lens, discomfort to asthmatics), the airline must still follow British quarantine and health regulations.

British Airways takes a preventive approach to food pests on its passenger aircraft. The premises of flight food caterers are inspected and codes of good practice must be followed (see British Airways' 'A Guide to Food Hygiene in Aircraft Catering'). Any insect infestations must be controlled on the premises or the caterer runs the risk of losing the contract.

In cargo planes, the problem is more often a rodent. It is recognized that it is difficult to prevent a rodent from coming aboard with cargo. Aircraft in which a rodent or evidence of a rodent (i.e., droppings) has been sighted are immediately grounded because of the risk of rodent damage to electronic controls and wires. The aircraft is fumigated with methyl bromide. To facilitate capture of the rodent body (and to avoid future foul odour problems), glue boards are set out just before the plane is fumigated. The chances are good that the rodent will get stuck in one of the glue boards when it becomes disturbed by the effects of the gas.

A regular inspection is also carried out by ground engineering staff during major or minor maintenance and, in some cases, by pest control contractors hired by British Airways.

When, for example, a cockroach is found on board an aircraft, disinsection may be carried out by a licensed exterminator following the 4.5 hour cleaning regime. In such cases, an approved residual insecticide (e.g., Brimpex ULV1500 [2.4% tetramethrin + 4.8% d-phenothrin]; Coopex WP [25% permethrin]; Ficam W [80% bendiocarb]; and/or Ficam Plus [bendiocarb + pyrethrins + piperonyl butoxide]) may be applied to problem areas in the galleys, toilets, and adjacent areas. Ficam is currently the most frequently used product.

6.3.2 Royal Air Force Policies and Procedures

Like British Airways, the Royal Air Force follows Port Authority regulations when aircraft return to the U.K. It follows WHO recommendations when flying into and out of specified countries where disease vectors may be involved. Fumigation, if and when necessary, is done using methyl bromide.

6.4 French Approach to Aircraft Disinsection

Air France follows WHO guidelines regarding cabin treatments with d-phenothrin aerosols when leaving certain listed countries. Disinsection of this type is basically aimed at killing mosquito vectors of disease (mainly malaria and yellow fever vectors) and is carried out by the cabin crew.

Residual spray treatments are usually carried out once per year in certain areas of the aircraft (e.g., the lower 10-20 cm of the cabin's interior walls, and the galleys and toilets) using a household insecticide product containing dichlorvos. Any insect problems that are sighted between times are dealt with immediately by maintenance staff.

Air France indicated that pest problems are very rare aboard their aircraft. Rodent problems were reported to be even more rare than insect problems. Fumigation would be carried out if a rat sighting was ever reported.

Regarding cargo aircraft, Air France occasionally transports livestock (e.g., race horses). To minimize post-transport cleaning problems, they have designed special self-contained animal containers.

Their emphasis, as far as pest management is concerned, concentrates on prevention

through good sanitation practices.

6.5 Netherlands Approach to Aircraft Disinsection

KLM Royal Dutch Airlines follow WHO recommendations ('blocks-away' aerosol spraying with d-phenothrin to control possible disease vectors) when leaving designated countries.

Following reports of insect sightings by air crew or maintenance staff, residual spraying with deltamethrin may be carried out. Occasionally, cockroaches, flies, fleas, and mosquitoes are reported. The use of insect glue traps is being considered.

Rodents are rarely found aboard their aircraft. Traps are used to capture them or rodent baits to kill them if they are reported. Flights into certain African and Caribbean countries are most prone to pest problems.

As with British Airways, hygiene inspections are carried out in the flight food caterers kitchens of foreign countries as part of their overall disease prevention program. A pest infestation, if found, is noted and must be corrected by the contractor.

6.6 Australian Approach to Aircraft Disinsection

Australia, like New Zealand, has been plagued with introduced pests, most brought by English-speaking settlers. Australia has very thorough and strict regulations on aircraft disinsection.

6.6.1 Australian Legislation

Under its Quarantine Act 1908 and Regulations, the Australian Quarantine and Inspection Service requires the operator of an international aircraft to treat the aircraft to kill insect or disease vectors either on or before the aircraft's arrival in Australia. The most recent schedule for aircraft disinsection procedures was approved in 1994. The procedures followed are very similar to those of New Zealand (see Section 6.7.1 below).

The purpose of their legislation is to prevent the introduction of a range of serious human, animal, and plant pests and diseases. No plants or animals or parts of animals may be introduced into Australia without the written permission of the Director of Quarantine, Department of Primary Industry and Energy.

The disinsection of aircraft cabins is aimed at human and animal health pests and diseases. Disinsection of aircraft holds is aimed at these pests and diseases plus those of plants.

6.6.2 Royal Australian Air Force Policies and Procedures

In addition to following WHO recommendations on aircraft disinsection, the Australian Quarantine and Inspection Service (AQIS) and the Royal Australian Air Force (RAAF) support the concept of vector (i.e., mosquito) surveillance and control in and around their international airports and RAAF bases. This latter program is in accordance with Article 19 of the WHO International Health Regulations. Although it has its weaknesses, the program serves as a back-up measure to

deal with any insect vectors of disease that are brought in by aircraft and escape the disinsection barrier. The key weakness is that mosquitoes outside the airport's control zone can still fly in, attracted to the airport lights, and enter aircraft.

Note that ports of entry, under the Australian Quarantine Act, include RAAF bases. Thus, Environmental Health staff are nominated as quarantine officers on RAAF bases where AQIS is not represented.

Aircraft disinsection policies and procedures and the clearance of aircraft arriving from overseas at RAAF bases are covered in their DI(AF) Pers 56.10 and their training manual (No. 7, Clearance of Aircraft and Naval Vessels).

RAAF quarantine staff will disinsect the military aircraft of foreign countries arriving at RAAF bases from overseas.

6.7 New Zealand Approach to Aircraft Disinsection

Of all the various Acts and regulations reviewed that deal with aircraft and pests, the legislation of New Zealand is the most thorough. Their efforts to prevent the introduction of pests into their country serve as an excellent model for the rest of the world.

6.7.1 New Zealand Legislation

Over the past 50 years, New Zealand (NZ) has required aircraft disinsection to protect itself from the establishment of insect pests and disease vectors (55). WHO recommendations have always been the basis of their aircraft disinsection requirements. They have rigorously stated that inconvenience to arriving passengers should not be used as an argument to relax their aircraft disinsection standards.

The NZ Ministry of Agriculture and Fisheries (MAF) recently published a 'Schedule of Aircraft Disinsection Procedures' to enable airline personnel to develop a detailed procedure and set of instructions applicable to their aircraft and operational methods. The aim is to destroy any exotic pests and diseases before they arrive in NZ.

Either of the following 2 basic methods can be used:

(1) A pre-flight application of a residual insecticide to the flight deck, toilet areas, overhead lockers, galley and crew rest areas, *plus* a 'top-of-descent' aerosol treatment of the passenger cabin. A certificate of cabin disinsection, signed by the purser, must be delivered to the quarantine officer at the airport upon arrival, prior to disembarking passengers. Also, all cans used for spraying must be kept for inspection and removal by MAF quarantine officials upon arrival at the first point of entry into the country.

(2) The residual treatment of all areas, including those listed above plus the cabin and hold areas, using 2% permethrin. The latter method requires prior approval, compliance with required record-keeping, and the issuance of 'certificates of residual disinsection'. To facilitate inspection for compliance purposes, using the latter method, a ultraviolet light tracer (Photine) must be added to the spray, prior to treatment. This method has some obvious

advantages to airline personnel and passengers, not least of which is the avoidance of any inconvenience.

This is the suggested, in-flight, pre-spraying announcement in the above schedule: 'Ladies and gentlemen, to conform with New Zealand animal, plant quarantine, and health requirements, the cabin will now be sprayed. The procedure, using a non-toxic spray recommended for this purpose by the World Health Organization, is necessary to avoid the introduction of harmful pests into New Zealand. Please remain seated and keep the aisles clear while the aircraft is being sprayed. Thank you'.

6.7.2 Quarantine Operations at NZ International Airports

At their international airports, trained NZ quarantine officials intercept plant and animal pests using several different approaches:

- Requiring aircraft disinsection, including residual insecticide sprays to cabins and holds and in-flight aerosol treatments, following World Health Organization recommendations.
- Inspection of aircraft cabins for any material that has been discarded by passengers and that may harbour pests.
- Inspection of aircraft cargo areas for evidence of commodity spillage and potential pests.
- Monitoring the removal and correct disposal of aircraft garbage, using such methods as incineration, maceration, boiling, or autoclaving.
- Signposting arrivals areas, notifying passengers of what materials must be declared and the penalties for failure to declare them, and providing amnesty bins so passengers can discard items that they do not wish to declare.
- Requiring arriving passengers to complete a declaration form, covering, in part, the importation of plant and animal materials.
- Observing and assessing arriving passengers in the baggage claim area to see what they are carrying and, if necessary, subjecting those with a risk profile to a search.
- X-raying baggage for low density materials (e.g., plants) and using 'detector dogs'.
- Inspecting freight of agricultural interest for pests. Goods are posted with a sign saying 'agricultural hold' until they are cleared.
- Air-bridges and baggage unloading areas are residually treated with permethrin.

6.7.3 Royal New Zealand Air Force Policies and Procedures

The Royal New Zealand Air Force complies with its country's legislation. A close rapport has been established between the Air Force and NZ quarantine officials.

7. Growing Opposition to In-flight Aircraft Disinsection

Every year, millions of airline passengers are exposed to aerosol sprays of insecticides on their flights overseas. Passengers leaving for many countries in the Caribbean, the South Pacific, and South-east Asia are sprayed while in flight at the insistence of their countries of destination.

The countries involved require the treat-

ment as part of their attempts to prevent the introduction of exotic agricultural pests into their country. Neither Canada nor the U.S.A. requires in-cabin spraying of flights arriving in these countries while passengers are present.

Flights are sprayed on descent into or upon arrival in the following countries:

- Antigua.
- Argentina.
- Australia.
- Barbados.
- Bolivia.
- Brazil.
- Chile.
- Columbia.
- Costa Rica.
- Ecuador.
- Grenada.
- Guam.
- Guatemalia.
- Honduras.
- Jamaica.
- Mexico.
- New Zealand.
- Nicaragua.
- Northern Marianas Islands.
- Panama.
- Peru.
- St. Lucia.
- Sint Maarten.
- Trinidad.
- Venezuela.

In addition, WHO recommends spraying the cabins of aircraft leaving certain countries to kill any disease vectors, usually mosquitoes, that may have entered the aircraft while in those countries. The spraying is aimed at preventing the spread of several diseases, including malaria and yellow fever. The countries involved are listed above.

In most cases, the pyrethroid insecticide used is d-phenothrin, a synthetic analog of the plant extract, pyrethrin. D-phenothrin is recommended for this purpose by WHO and is registered for this purpose by the pesticide control agencies of many countries.

7.1 Health Concerns of the General Public

Although there is considerable merit in carrying out these insecticide treatments, there is increasing resistance to its use. In recent years, hardly a month goes by without a newspaper or magazine article somewhere condemning the practice. Opponents of this type of spraying (indeed, any type of spraying) argue that exposure to such insecticides may cause cancer, increased chemical sensitivity, allergic reactions, eye and skin problems, and so on, especially amongst individuals already suffering from some medical disorder. They also question its effectiveness, particularly its ability to penetrate luggage and briefcases, where certain pests may be present but protected from the spray.

7.2 Concerns about Chloroflurocarbon Propellents

Opponents of aircraft disinsection, particularly the use of insecticidal aerosols also point out that chloroflurocarbons (CFCs) are being used as propellents. CFCs are believed to be a major cause of ozone depletion in the upper atmosphere. Although research into alternative formula-

tions is always ongoing (e.g., water-based formulations by Sullivan *et al.* [100, 102]) and new aerosol formulations are now being manufactured without CFCs (e.g., using CO_2), it may be many years before the older formulations are all replaced with ones meeting the strict safety requirements aboard aircraft, especially those for a non-flammable propellent and a non-corrosive deposit.

PART B. TECHNOLOGY: METHODS, EQUIPMENT, AND MATERIALS

1. Introduction

This portion of the study of aircraft disinsection deals with the methods, equipment, and materials used in monitoring for, preventing, and dealing with infestations of pests aboard aircraft. An integrated pest management approach is recommended, emphasizing the use of preventive and non-chemical strategies where possible.

2. Early Research on Insects in Aircraft

Kisluik (42) probably started the field of research dealing with aircraft disinsection when he inspected the large, lighter-than-air craft *Graf Zeppelin* in 1928. He found 10 species of insect pests on-board. Since then, researchers have been trying to find acceptable ways of preventing pests from boarding aircraft and, when pests are found, ways of controlling them.

The health risks associated with insects were considered paramount in the early years. Pest management research centred on the development of aerosol equipment for disseminating insecticides in airplanes to kill disease vectors (24, 25, 27, 30, 31, 39, 65, 73, 85, 91, 92, 93, 96, 98, 99). The key development was Iddings' research (39) that made insecticides self-propelled by using Freon. Several authors have reviewed these studies (20, 21, 22, 28, 76, 79, 87, 100, 101).

Research was also carried out on the ability of insects to survive temperature extremes, atmospheric changes, and high g-forces (43, 44, 71, 86, 94, 95).

It was later observed that insects can hitch-hike both outside and inside the aircraft (46-52). The flying or crawling stages of insects can stow-away inside wheel wells. Insect eggs can be laid anywhere on the outside surfaces of an aircraft (47). If the egg-infested aircraft sits for several days upon arrival back at its base from a foreign country, the eggs may hatch and the hungry larvae may move to a suitable host plant, threatening local agriculture or forestry.

3. Sources of Aircraft Infestations

Insect infestations are much more common on aircraft than many people would suspect. They may enter standing aircraft through open doors and windows, with cargo, or with passengers' belongings (64, 90).

3.1 Doors and Windows

A transport aircraft, parked on the ramp after unloading, can become as hot as a furnace in the tropics. Every door and window that can be opened is usually opened to provide air crew and maintenance workers with some cooler air.

At night, when the interior lights are on, such an aircraft becomes a huge insect light trap. Insects will be drawn into the aircraft through every opening. Any time that an aircraft is left open for crew or passenger boarding, cargo movement, or maintenance, it is vulnerable to infestation.

3.2 Cargo

There has been a global increase in the handling and transportation of cargo con-

tainers by aircraft. Commercial aircraft often carry fresh fruit, vegetables and flowers. Military aircraft may be used to move cartons or bags of food to or within famine-ravaged countries. All of these materials may attract or be infested with a wide variety of pests.

Cargo containers provide a relatively stable and undisturbed environment for a stowaway pest. If cargo sits dockside or in a humid warehouse for several days, some cockroaches, grain beetles or rats will likely take up residence. Once inside the cargo and aboard the aircraft, they may spread throughout the plane.

Cockroaches are probably the most common aircraft pests. They are often brought on board in food service carts or modules. These modules are often insulated to keep food warm. Unless completely sealed, the airspace between the two surfaces can provide an ideal harbourage for cockroaches. Once on board, the hungry cockroaches can move to other areas of the aircraft undetected.

Flour and grain beetles may be attracted to aircraft that have been carrying sacks of flour, beans, rice, or other dry foods. Sitting on a hot tarmac with the doors open, such an aircraft must smell like a rich source of food to these stored product pests.

Flying, adult mosquitoes may enter aircraft, directly, through open doors or windows or, indirectly, in cargo (35). Vehicles, as cargo in military aircraft, are often overlooked as a source of such mosquitoes. Even larval mosquitoes may be inadvertently transported by aircraft. The larvae may be present in pools of water formed by creases in a tarpaulin covering cargo or in a variety of containers (e.g., supposedly empty drums, tires).

A rodent usually comes on board with cargo. It may also gain entry by crawling up landing gear, passenger staircases, loading and maintenance platforms, and service and drainage lines.

3.3 Passengers' Belongings

Common household pests (e.g., ants, bedbugs, lice, fleas, spiders and cockroaches) may board a plane with a passenger's carry-on food, clothing, or luggage. These pests can spread from passenger to passenger or place to place on the aircraft.

4. Aircraft as Harbours for Pests

Once inside an aircraft, pests may take up temporary or permanent residence. Aircraft make good homes for a variety of pests because the cabin has all the necessities for survival. Cabin areas provide warmth, food, water, breeding areas, and spots free of a pest's natural enemies.

Many factors favour a pest's survival aboard aircraft. Even at the most frigid stopovers, climate-controlled cabins maintain adequate warmth within the aircraft for even tropical pests. In addition, pests find adequate water supplies from faucets, toilets and condensation.

The galley is a source of food for people and pests alike. This area is a problem because it is cramped and difficult to clean. Spilled food collects in hard-to-reach crevices. The galley tends to stay warm long after the equipment is shut

down. Because steam is often used to keep food warm, this area is usually very humid. These conditions attract a wide variety of insects, especially cockroaches. In addition, food carts are often constructed of hollow tubing. These carts can attract, harbour, and spread pests throughout the cabin.

Passengers may eat food throughout the cabin, sometimes even in the toilets. The food may be either brought on or provided in flight. Passengers may spill sweetened drinks on the floor, drop food crumbs into the seats, and forget bagged lunches or left-overs that they tucked into seat pockets or overhead storage compartments.

Aircraft cabins and holds are full of crevices that provide safe locations for pest breeding and harbour. Clothes lockers, overhead and under-seat storage areas, and seat pockets can become infested and serve as reservoirs for pests.

Power and communications lines, ventilation ducts and openings for water pipes, that run the length of the aircraft, allow easy movement of pests throughout the plane. Standard aircraft construction creates voids in walls, floors, ceilings and around machinery. For all these reasons, widespread infestation may occur, often at considerable distances from the galley and food storage compartments.

5. Pest Survival at Destinations

Insect stowaways cannot adapt to the local environment at every destination. Tropical cockroaches would not last long outdoors, especially during the winter, in any northern climate. Many insects would be not be able to adjust to different photoperiods and weather conditions (32, 33). However, some pests might find the perfect harbour in a heated hangar, terminal or aircraft where the essential needs of shelter, warmth, moisture, and food are met. A hanger's lunchroom, a terminal's restaurant, or a caterer's kitchen may meet all of the environmental requirements of these insect pests. However, the introduced populations of most tropical insects would probably die out as soon as they encountered the relatively severe winters that occur throughout countries like Canada.

Probably the most important introduced pest is one entering a country from another temperate region of the world (e.g., Europe, Asia, South Africa, South America). If the pest's environmental requirements are met, the pest population could explode in the absence of the natural enemies that normally would keep them it check.

To prevent a pest from boarding aircraft and being transported successfully to another country, causing all sorts of health and economic problems, a wealth of technology has been developed over the years.

6. Planning an Integrated Aircraft Pest Management Program

Airlines and military establishments around the world have recognized the problem of pests on aircraft for years. Concerted efforts have been made by WHO and other agencies to control these uninvited pests, especially those able to carry disease.

Until the mid-1980's, the standard treat-

ment for the control of aircraft pests usually consisted of routine broadcast spraying with a conventional chemical insecticide (64). Inspection for the presence and distribution of pests inside aircraft was rare. Often, the entire aircraft was treated, regardless of whether or not any pests were seen.

The pesticides used were often smelly and irritating, especially to the maintenance staff, aircraft crew, and passengers who had to live with a lingering odour. Since the mid-1980's, advances in application equipment and techniques and the development of new, low-odour, pesticide formulations have been a welcome change to aircraft pest management.

In recent years, the management of some large, commercial and military aircraft fleets have developed comprehensive, integrated aircraft pest management programs to improve the comfort and protection of crew and passengers and to meet international quarantine regulations (64). A variety of approaches have been taken.

Because these include preventive and non-chemical measures, they can be considered to be integrated pest management programs. Improved preventive sanitation practices, thorough aircraft and cargo inspections and cleaning (with insecticide treatment, when and where necessary) have become standard operating procedures for most of the world's major international airlines and many of the larger military establishments.

7. Monitoring for Pests

Thorough checks of aircraft returning from deployment overseas will invariably reveal the presence of some pests, either living or dead. Because many insects and insect parts are tiny and inconspicuous (especially the dead ones), they are easily overlooked by air crew and maintenance staff. However, someone trained in the basics of entomology (e.g., loadmasters and preventive medicine technicians) will have no problem finding evidence of insect pests. Perhaps, a 'bug look' should be added to the checklist of the loadmaster before a transport aircraft leaves a country to return home.

7.1 Monitoring for Insects and Their Allies

If possible, pest management personnel should consult with air crew and cleaning and maintenance personnel before beginning to monitor for any pests. These people are often the best sources of information about the location of an existing pest problem.

The aircraft should be inspected thoroughly. A pest management person should look for the pests and any evidence of their presence. Specifically, he/she should look for dead and living insects, insect egg capsules, insect faecal pellets and characteristic odours (64).

Military and commercial airline safety policies usually prohibit the removal of access panels by untrained personnel. If a pest management person needs to inspect an inaccessible area of the plane for insects, he/she should discuss the need for special access with an *authorized* maintenance person. Only a qualified aircraft maintenance technician should remove and replace a panel.

Because foreign pests may be found on aircraft returning to base, it is important that they be collected, preserved, and carefully identified. Monitoring personnel should cooperate fully with the quarantine officials. These agricultural officials can facilitate identifications and advise on proper monitoring methods for specific pests.

Persons involved in monitoring should record all of their observations. Over time, their notes can be reviewed and used to determine pest trends. Well-kept records can be an important component of an integrated pest management program for aircraft.

Where possible, pest management personnel should be aware of transportation and maintenance schedules. This information will assist them in facilitating, if not scheduling, future monitoring and treatment. Although regular monitoring may be reasonably easy with commercial airlines, this may not always be the case when military aircraft are involved.

Pests can be found on and in aircraft in almost every conceivable area (50), from exterior surfaces of the fuselage, to wheel wells, to passenger and cargo compartments, to baggage. The invertebrate pests are most common, in particular spiders and insects. Spiders and insects may be simply temporary passengers or, in the worst case, established populations. The temporary pests, often seen flying around the cabin or crawling on the floor or window ledges (trying to get out), are usually the easiest to find. The established ones, often seeking shelter and moisture in cracks and crevices and food where they can find it, are the hardest to find and destroy.

Some places to look for these pests aboard an aircraft are listed below:

- Mosquitoes - check window ledges for dead and dying mosquitoes.

- Nuisance Flies - check window ledges for crawling or dead house flies and blow flies.

- Fly Maggots - check rotting food garbage.

- Cockroaches - check galleys and food storage areas.

- Ants, bees, and wasps - check around garbage containers and all window areas, including those on the flight deck

- Grain Insects - check accumulations of spilled grains on and under floor panels.

- Moth Eggs - check all exterior surfaces of the fuselage for clusters.

- Spiders - check dark, secluded recesses of the hold and of the cargo, especially on any equipment, machinery, vehicles, cargo pallets, spare aircraft parts that were stored on the ground in the country of deployment.

When inspecting for cockroaches and other cryptic insects that typically hide during the day in dark cracks, crevices, and spaces, some workers, called in to control a pest problem, first use a pyrethrin aerosol spray to dislodge the insects from their harbourages and to pinpoint those locations requiring a residual insecticide spray.

Remember that pyrethrin has little or no residual efficacy.

For transport aircraft (e.g., Hercules), some key areas require regular and careful monitoring. These areas include the voids beneath the floor panels and behind the insulation batts. The areas beneath the floor panels can be monitoring with special sticky traps (e.g., Catchmaster Roach Monitors; Agrisense's Detector and Lo-Line Traps). When checking insulation batts, first look behind those batts that are near interior lighting panels. Because insects are attracted to lights at night, they frequently hide behind the batts close to the interior lights (78).

7.2 Monitoring for Rodents

Monitoring for rats and mice is relatively easy because of their size and their habits. Basically, rodents are either sighted and reported by air crew or passengers or their droppings are found (often on or under the floor panels) near food. Sometimes, nests are found when panels or covers are removed from aircraft equipment or fixtures. In the worst case, gnawed wires or cables are discovered when a maintenance person is tracing some reported malfunction.

7.3 Monitoring for Accumulations of Soil

Dirt typically is deposited along corridors by foot traffic and under cargo, especially vehicles and other equipment that is used in the field and is loaded onto the aircraft without first being cleaned. Inevitably, the dirt moves to the edges of the floor and finds its way down to sub-floor spaces through openings, vents, and cracks and crevices.

If it was 'pure' dirt, it would not be a problem. Unfortunately, dirt may be laden with bacteria, fungi, nematodes, insect eggs, and other nasty organisms that could threaten agriculture and forestry, if not human health, when brought back home. It may also contain materials that are corrosive to aircraft components.

The person monitoring for the accumulation of soil should inspect the crevices along the edges of floors and, after a series of floor panels are removed, the sub-floor spaces. In some cases, dirt may have been blown about the aircraft as dust and it may cover all horizontal surfaces.

8. Tools used for Pest Monitoring and Collecting

Inspecting for pests aboard aircraft varies with the type of aircraft involved. Each type of aircraft will have unique a unique number of pest harbours. Inspectors should have a basic design sketch of the aircraft involved to study before carrying out the inspection.

A checklist of pest monitoring tools for preventive medicine technicians should include the following:

- Approved (explosion-proof) high-intensity flashlight.
- Clipboard, forms, and pen.
- Aspirator, tweezers, forceps, and hobby paint brush.
- Collecting jars, zip-lock bags and alcohol-filled vials.
- Mechanic's extension mirror.
- Sticky traps to help locate harbours.
- Pocket knife for probing cracks and crevices.

- Hand-lens or magnifier.
- Aerosol can of pyrethrin flushing agent.

Although most of the equipment used is readily available locally, some items are best obtained from a biological supply company. These items should be part of the kit of every person inspecting an aircraft for pests.

9. Monitoring Records

When insects or other animals are collected on board aircraft, records should be kept of each occurrence. Specially-designed record sheets or, at least, a notebook for recording any observations made during the inspection are very important. If only certain types of aircraft are involved, special forms, including general diagrams of the aircraft, can be incorporated into the form to enhance record-keeping. Good record-keeping will facilitate any necessary follow-up that may be necessary.

The minimum information kept should include the following:

- Collection reference number.
- Collector's full name, rank, or position.
- Type of aircraft.
- Route flown in full.
- Date of arrival back at airfield/airport.
- Date collection made.
- Note whether insects were dead or alive.
- Disposition of insect specimens.
- Identifications made.

10. Pest Management

Neither management nor air crew want a random insecticide application in an aircraft (64). An insecticide treatment should only be made when and where it is necessary. If it is determined that there is an insect problem, controlling it with a specially-designed bait formulation should be considered. If an insect problem is only suspected, a sticky trap should be strategically placed to see if it can pick up anything on future inspections. If an aircraft does not have a pest problem, nothing should be done.

In the old days, some exterminators simply came on board with their compressed air sprayers and sprayed wherever they could without much thought of the pest involved or its habits. Spraying was done on a calendar basis. Today, the pest control technician, faced with an insect problem, is much more cautious. After carrying out an inspection in response to a complaint, the pest manager may not even use a sprayer. To kill a few secretive insects, only small amounts of an insecticidal bait may be used.

The bait may be applied to selected insect hiding spots, perhaps with a hypodermic syringe or a small putty knife. Or, the technician may fasten small, containerized baits behind straps and other restraints. In a building, these adhesive-backed bait stations or traps may be stuck to the wall or the bottom of a drawer. In an aircraft, fine dust or cold temperatures may render the adhesive useless. Aircraft maintenance workers can advise on which areas may get hot or cold and which areas are seldom disturbed and would make good places to put bait stations or traps.

Insecticidal sprays are only used when and

where necessary. An insecticide should never be sprayed in the cockpit. Drift or fumes may cause short-circuits or damage sensitive electronic equipment. However, insect bait stations may be used, in certain cases, in this area of the cabin. In a cockpit, the control panels are sometimes held in place by velcro. Under the panels, the instruments may look like a stereo rack with each device slid into its respective place. Maintenance staff can advise on whether or not bait stations can safely be placed amongst this equipment and where they are most secure.

Sometimes, there must be a compromise between where the maintenance person will allow a bait to be placed and where the pest control technician thinks it is required. The pest control technician should not touch anything in the cockpit without the prior permission of the maintenance escort. If necessary, the bait containers can sometimes be trimmed to make them fit snugly in a tight spot. To prevent any of the bait containers from vibrating loose, they can sometimes be slid behind a velcro strap or other restraint to lock them into place.

Some pest control companies, regularly involved in aircraft disinsection, have designed booklets that correspond to the aircrafts' maintenance books. Thus, airline personnel can then easily record any pest sightings and problems without the burden of additional paperwork.

Such pest control companies may also work closely with airport caterers. Caterers are usually eager to help. They do not want to be known as a company that infests aircraft with pests.

11. Non-Chemical Pest Management Methods

11.1 Prevention

As with any pest problem, a milligram of prevention is worth a kilogram of cure. When considering prevention, the aircraft, the airport facility, passengers, and the goods brought on board should all be considered.

11.1.1 The Aircraft

Pests can be prevented from entering and moving throughout the aircraft in several ways: e.g.,

- Close aircraft doors if the aircraft is not in service.
- Correct any plumbing or ventilation leaks.
- Improve food-handling techniques.
- Thoroughly clean cabins, galleys, bars, and toilets.
- Caulk crevices on food modules.
- Keep food waste in sealed containers while on board.
- Remove and dispose of food waste immediately.
- Seal cracks and crevices in aircraft furnishings.

11.1.2 The Airport Facility

To further reduce the likelihood of infestation inside aircraft, pest management personnel should also develop a series of IPM strategies for airport facilities. Any pest infestation on an airport facility will invariable spread to the planes that are serviced by that airport. Although other personnel may service these areas, pest managers

should offer suggestions to the facility's management on how to eliminate these problems.

Pest management personnel should also advise management on practical ways to pest-proof buildings and to manage existing insect, reptile, bird, and rodent infestations (e.g., locating and caulking exterior cracks and crevices on a food caterer's building can be an effective non-chemical measure; using sodium vapour bulbs for building and ramp illumination will minimize the chances of flying insects invading a facility). Building maintenance management staff should be encouraged to read and use IPM methods and materials.

11.1.3 The Passengers and Cargo

Often, there is nothing that can be done to stop passengers from bringing food on board an aircraft or leaving food and other garbage on the plane when they disembark. If returning from abroad, they and their luggage are subject to inspection by agricultural quarantine staff who may find and confiscate products infested with insects. That may still leave pests aboard.

Thus, cleaning of the aircraft, after the passengers leave, should be carried out immediately. Discarded food and other materials should be picked up and sealed in plastic bags for later disposal (see Section 11.1.7 below). Seats, pockets, bins, and carpeting should be then be cleaned and vacuumed. The bag from the vacuum cleaner should be sealed in a plastic bag for later disposal.

Wooden pallets, used for carrying food materials and equipment, may harbour a variety of snails, spiders, and wood-boring pests. If they are infested with wood-boring insects, they must be burned or fumigated. A non-chemical alternative is the newer, plastic-based pallet. It is made from recycled materials and will stop the wood-borers. However, they must still be inspected for other pests.

If transport aircraft are to be loaded at night on rough strips, using military lighting, sodium vapour lamps should be considered. Although they are not completely unattractive to night-flying insects, they are far less attractive than standard lighting.

11.1.4 Spilled Food Materials in Transport Aircraft

Waste food materials, spilled from previous consignments of grain and lentils, must be cleaned up before departure from the country where the aid program took place. These spilled materials may include weed seeds and microorganisms. Spilled grains can be highly attractive to grain-destroying insects, mice, and rats.

The weed seeds, microorganisms, and insects all pose a risk to home agriculture. Accumulations of rotting, organic matter in the belly of the aircraft may be corrosive to aluminum and other metal components. The rodents, because of their gnawing habits, may damage electrical components of the aircraft and, thereby, seriously threaten air crew and passenger safety.

11.1.5 Vacuuming

Because both fixed- and rotary-wing transport aircraft must frequently operate out of unprepared runways and airfields, they tend to accumulate sand, dust, and organic debris. All accumulations of food grains,

weed seeds, and/or soil on the flight deck, cargo hold, toilet areas, galley, lockers, and items of cargo to be unloaded from the transport aircraft must be removed.

There are many different kinds of vacuum cleaners that are suitable for general cleaning in aircraft during routine maintenance while deployed in a foreign country (see Conclusions and Recommendations below). The vacuum cleaner should become part of the aircraft's equipment list and the responsibility of the air crew. For transport aircraft, responsibility for the equipment is best delegated to the loadmaster.

There is always some down-time when a transport aircraft can be thoroughly vacuumed (e.g., during repairs, poor weather). If required on a weekly or biweekly basis, vacuuming would reduce the chances of spilled food materials and soil settling out in the bottom of, for example, a C130 aircraft, sometimes not to be discovered for many months. Vacuuming should also be done before take-off, immediately before leaving a country, whenever operations permit.

If helicopters are used to move raw food commodities in a foreign country, there is ample time to vacuum out the aircraft below the floor panels while the helicopter is being shipped back to base. This should be the responsibility of the flight engineer.

Surveillance aircraft (e.g., P3 Aurora, Nimrod) and search and rescue aircraft (e.g., Buffalo, Dash-8), as well as passenger aircraft (e.g., Airbus A310, Boeing 707), should be vacuumed on a regular basis. In the latter case, cleaning could be carried out when the aircraft lands at international airports by airport cleaning service personnel. This should be the responsibility of the flight engineer.

Some C130 aircraft come equipped with a vacuum hose which, when hooked up to an outside vent while the aircraft is in flight, creates a vacuum. They are simple, lightweight, and cheap. This system, obviously, does not work while the aircraft is on the ground. One particular vacuum seems ideal for insect control on aircraft. It is called the 'Li'l Hummer'. It has become very popular amongst pest control companies in recent years. This small, lightweight (less than 5 kg) back-pack vacuum, powered by a hospital-quiet 9.6 amp motor, pulls insects, insect cast skins, insect food, and dirt out of cracks and crevices. However, this unit is not classified as explosion-proof and, thus, may not meet aircraft safety requirements. This piece of equipment should be evaluated to determine if it meets or can be slightly modified to meet these requirements. If an explosion-proof vacuum unit is required, canister models are available from various suppliers.

11.1.6 Air and Cold Washing

Previously, some crew members simply opened the rear door of the C130 while in flight, setting up a wind storm that cleared a lot of dirt and garbage out the back door. Safety questions aside, this method is neither effective nor acceptable. Debris and pests under the floor panels will not be removed. Caked on dirt will not be lifted. Indeed, some food residues and other materials might end up in relatively inaccessible areas, making matters worse.

Cold washing (leaving an arriving aircraft

outdoors during the winter at ambient sub-freezing temperatures) is also an unreliable means of killing pest infestations aboard an aircraft. Although some tropical species might succumb, many insects simply slow down their metabolism in response to freezing temperature, resuming their activity when they warm up.

11.1.7 Handling and Disposal of Aircraft Garbage

Food garbage attracts pests. Aircraft cabins should be routinely examined for any materials discarded by passengers, especially any materials that may harbour pests or diseases. In particular, the inspector should be watching for any 'empty' food containers, scraps of food (e.g., fruit, meat, cheese), live animals (e.g., insects, snakes, birds, amphibians), seeds, and meat products.

The careful removal and proper disposal of garbage is a vital component of plant and animal quarantine. Every effort must be made to leave all garbage behind before leaving a foreign country, disposing of it according to local guidelines, if any apply.

Any garbage brought back must be handled carefully. Upon return to base, air crew and cabin staff should secure any accumulated garbage in labelled plastic bags. These should be removed by air crew or maintenance staff and disposed of in an airport or base incinerator or at an approved landfill site.

For aircraft undergoing maintenance upon return to base, the maintenance personnel should be aware of possible pest infestations. If insects or spilled food materials are discovered when removing panels, all materials should be vacuumed up immediately and sealed in a clearly-labelled, plastic bag (including the name of maintainer, aircraft tail number, and the date on the label). The maintainers should immediately report their findings to the preventive medicine technician who will inspect the aircraft further, collect the sealed bag for proper disposal, analysis, or delivery to quarantine officials. The preventive medicine technician will also carry-out or arrange for the disinsection of the aircraft, if and when necessary.

11.1.8 Military Cargo

Military transport aircraft may be required to carry a wide variety of equipment and materials. When such cargo is being returned from abroad, every effort should be made to ensure that it is free of pests before loading. It will be inspected by agriculture officials upon arrival.

Such efforts should include a careful visual assessment of any obvious pests and soil. Whereas rats and mice and even most insects can be detected by careful inspection for the pests themselves or evidence of their presence, very intensive inspections are necessary to detect small amounts of soil and some pests (e.g., the eggs of many insects).

Infested cargo can often be washed or steam-cleaned to remove all soil and pests. Information on contingency retrograde washdowns procedures for military vehicles is included in a recent USDoD report (89). When cleaning is not possible, the cargo may have to be fumigated before it brought on-board.

11.2 Public Education

Everyone in military service and their dependents who takes an international flight needs to know that pests can be transported by aircraft and that precautions should be taken to prevent pests from being brought home.

11.2.1 Educational Materials

Education is the key to preventing pests from coming on board aircraft. Departure lounges for passengers leaving a foreign country should contain information on the importance of not returning home with illegal materials that may pose a quarantine risk. This public education exercise may prevent some people from placing themselves in a situation where they must either discard, declare, or smuggle materials that may contain pests.

11.2.2 Airport Signage and Amnesty Bins

Many international airports post signs, usually somewhere enroute to their customs and immigration barriers, describing items which cannot be imported into the country. The penalties for smuggling live birds, plants, seeds, and meat products may also be clearly stated. Passengers are warned to declare any questionable items or to discard these items into the amnesty bins provided.

In most countries, arriving passengers must sign a declaration form which, in part, states that they are not carrying any plant or animal materials. If they declare that they do have such materials, they are routinely inspected by an agricultural quarantine official. Quarantine officials at many airports report that these measures have been successful in reducing the chances of introducing pests through ignorance of the consequences. Military personnel, including both air crew and passengers, should be briefed on the importance of these rules and warned of the consequences if they are ignored.

Air forces should seriously consider setting up their own signage and amnesty bins for military personnel arriving directly at airports where these personnel are not usually subject to federal inspection. Air force personnel should meet with agriculture officials for advice on the various protocols involved (e.g., information provided on signs, size and type of amnesty bin, inspection and handling of materials deposited, liaison with quarantine officials).

12. Chemical Pest Management Methods

The first suggested procedures for aircraft disinsection were included in the 1933 edition of the International Sanitary Convention for Aerial Navigation. By 1937, pyrethrins were used for in-flight disinsection. In 1944, DDT was used for this purpose. In 1951, WHO became involved (72).

WHO recommended disinsection before take-off, after the cargo and baggage was loaded but before the passengers were boarded. This policy was reaffirmed in 1957 (78). WHO considered airport disinsection (of disease vectors) the more important procedure. Later, WHO recommended disinsection after the passengers boarded but before take-off because disease vectors were found to enter the aircraft with the passengers and to survive the flight (106). A mixture of 3% DDT and 1.6% pyrethrins was recommended.

Still later, vapour treatments were recommended, using Vapona (dichlorvos) through an automatic dispensing system (e.g., 41, 59, 68). Studies suggested it was safe to crew and passengers (105). However, this practice was discontinued when it was found that, over time, dichlorvos may cause damage to some aircraft components. In the early 1970's, various synthetic pyrethroids were discovered and evaluated (97). Resmethrin was the most promising. Then, 20 years ago, continued research into new products for aircraft disinsection led to another synthetic pyrethroid, d-phenothrin (83). A 2% formulation, with Freon 11 and 12 (in a 1:1 ratio), gave both good knockdown and kill of test insects. It had all of the desirable characteristics of an insecticide aerosol to be used in aircraft.

Eventually, most operators of civilian and military aircraft switched to 'blocks-away', in-flight, or 'top-of-descent' aerosol applications of d-phenothrin, when flying into countries requiring disinsection for quarantine purposes or when flying out of countries where disease vectors may have come on board the aircraft with the passengers, baggage, and/or cargo (75, 78). This is often supplemented with a periodic residual treatment of insecticide to the flight deck, galleys, lockers, and toilet areas.

12.1 Chemical Pest Management Decision-making

Sometimes, monitoring, prevention, and the judicious use of insect baits is not enough to prevent an infestation on board an aircraft. As with other pest management programs, the choice of methods and materials to use will depend on the results of the initial inspection. If an aircraft suffers from a well-established infestation, the initial treatment should focus on eliminating that infestation using chemical measures. Non-chemical measures often take time to implement and, if used alone, will seldom eliminate an infestation. However, once an aircraft is free of pests, IPM techniques will reduce both the likelihood and the impact of any future pest infestations. A thorough treatment is especially important for controlling fast-breeding pests (e.g., German cockroaches), where a population reduction of less than 100% is unacceptable.

With the help of air crew, records of all aircraft inspections and treatments, galley-module treatments, and aircraft cleaning should be kept for and with that aircraft. In the case of military aircraft, the base's preventive medicine technician must be notified before a pest control worker is allowed on an aircraft. The safety of the air crew and aircraft is the foremost concern. There must be no confusion as to where an insecticide has been applied. The preventive medicine technician should record what the pest is, what insecticide will be used, and where it is to be used.

Wherever possible, pest management personnel should make follow-up inspections after the initial insecticide treatments (64). If any pockets of insect infestations remain, they should be eliminated with spot treatments. Although a new pest might board the aircraft in the future, the most certain source of pest problems will be from insects that survive the initial treatment. These survivors are in a better position to breed than new, unestablished invaders. After the initial treatment and the follow-up inspection, monitoring becomes the primary service performed by pest manage-

ment personnel. Aircraft with a history of infestation will require more frequent inspections to determine the need for follow-up treatments.

Pest sightings should be recorded because they may help to pinpoint insect problems. In some situations, the pest may be an isolated individual rather than representative of an established infestation. Routine insecticide treatment might not be necessary. In such cases, the focus should be on inspections and IPM measures aimed at preventing infestations.

Pest invaders should be tracked by placing monitoring traps in areas not visible to crew or passengers. The pest management personnel can then estimate the population level of the pest and implement appropriate treatment strategies to prevent a re-infestation.

Special care should be taken to eliminate pests in the food services department. Galley modules should be treated on the ground before they are placed on the aircraft. If the modules are numbered, the service vendor can keep a log of their inspection and treatment. Without the cooperation of the caterers, control of such insect pests as cockroaches will be difficult.

In addition, ground facilities(e.g., shops, restaurants, hangars and storage) might be handled by different contractors. Limited accountability and multiple contractors increase the likelihood of an aircraft pest infestation. With the help of airport management, pest management personnel should coordinate their control efforts with these groups. The same principles should be used at air force bases.

If pesticides are applied on board an aircraft, shortly before staff and other contractors arrive, pest management personnel should establish a communication program to help management respond to any employee concerns about the treatments. Pest management personnel should point out that many of the pesticides used on aircraft are the same as those that are used to keep restaurants, hospitals, nursing homes, and schools pest-free.

12.2 Scheduling Insecticide Treatments

The key to aircraft pest control is the scheduling of the pest control technician's time on the job. Aircraft represent a particular safety challenge when it comes to the application of any insecticides. Therefore, any technician who services aircraft should have special training Generally, a pest control technician can service aircraft cabins during the late-night or early-morning hours, when most aircraft are down for maintenance or are between flights.

With military aircraft, the person in charge of the aircraft while it is on the ramp or in the hanger should handle the scheduling of aircraft disinsection in cooperation with the preventive medicine technician. The technician will do the disinsection or interface with the contracted pest manager.

Servicing should include monitoring, bait placements, and spot treatments, as necessary. External insecticide treatments (i.e., recesses for landing gear) are best done just before the aircraft leaves an airport to return home. Cargo and cargo areas are best treated after the cargo has been loaded and just before the cargo bay doors are sealed. Cabin aerosol treatments,

carried out for quarantine purposes, are often done by air crew, during taxiing.

12.3 Insecticide Selection

Various authors have developed sets of criteria for selecting an insecticide for use in aircraft (81). Their combined 12 criteria can be summarized as follows:

- Toxic to a wide spectrum of insect pests.
- Residual activity of 1-2 days.
- Low toxicity to crew and passengers.
- Stable in aerosol or dust formulations.
- Readily dispersible.
- Little or no odour.
- Non-irritating.
- Non-staining.
- No effects on avionics, metals, fabrics, or plastics.
- Formulated, if an aerosol, in a high concentration.
- Dischargeable within 1-2 minutes
- Applied before any food or drink is served.

Because of their lingering odour, corrosiveness or flammability, some materials are prohibited on aircraft. Such materials may corrode an aircraft's structural components, which, in turn, may impair the aircraft's performance and endanger lives. For example, reactive solvents can cause window fogging or etching and fabric discoloration. Dusts or volatile ingredients, in various formulations, can move to areas not targeted for pest control, possibly causing discomfort or irritation to air crew or passengers. Broadcast applications should be limited to controlling an extensive infestation (e.g., a heavy flea infestation).

Although several insecticides can be used on aircraft, some labels are very specific about the areas of application. Following specific label directions for the product will prevent damage to the aircraft while providing control of the target pest. *Unless 'aircraft' or 'plane' is a listed site on the product label, it has not been approved for this specific type of application.* Contact regulatory officials and the manufacturer and obtain clear, written directions on its safe use on aircraft before using it. With passenger safety and company liability in mind, some fleet operators demand proof that a pesticide formulation is non-corrosive before they will allow its use on board the aircraft.

Currently, a permethrin residual treatment is being actively promoted by WHO and by quarantine officials from many countries. The adoption of this method of aircraft disinsection would be an effective means of controlling both medically and agriculturally important insect pests on board aircraft flying international routes.

Some areas of an aircraft, such as the cockpit and electrical bays, cannot be treated with chemicals. If insects invade these sensitive sites, pest management personnel must use monitoring traps or modified bait stations to collect and remove the insects.

Another factor to consider when selecting chemicals is that cleaning measures on planes can be quite rigorous and tend to decrease pesticide efficacy. Insecticides should not be applied to surfaces that will be thoroughly cleaned shortly afterwards.

Cabin aerosol treatments, carried out for quarantine purposes, can be an effective

means of dealing with flying and crawling insects (15, 56, 58). They may involve the use of multiple-use or one-shot aerosol cans or special injection systems.

Insecticides that have been used with some success include dichlorvos, various mixtures of methoxychlor and synergized pyrethrins as well as such synthetic pyrethroids as d-phenothrin, resmethrin, cyfluthrin, and permethrin.

Currently, the only aerosol specifically registered for use on aircraft in Canada is Bugcon Super Space & Contact Residual Insecticide Solution (containing 0.7% pyrethrins and 4.0% piperonyl butoxide). Aircraft flying outside of Canada are not limited to this product. Other insecticides, purchased in other countries and held in bond while in Canada, may be used outside Canada.

12.4 Equipment and Materials Used in Chemical Pest Management

When considering the use of chemical options for pest management, a variety of equipment and materials must be available. First, the applicators must have suitable protective clothing, including such basics as coveralls, chemical-resistant neoprene gloves, vented goggles, an agricultural respirator, and rubber boots. Generally, ear and head protection will also be required.

In addition, the person doing the application will require a supply of the pesticides that will be used and the proper equipment for their application. In an aircraft, the equipment requirements are fairly simple: i.e., a 2-gallon stainless steel sprayer, equipped with a multijet crack and crevice tip assembly and pressure regulator (e.g., B&G Equipment Professional Sprayer Model 594), and a carrying case designed for the sprayer and its accessories.

The pesticides used may include several insecticides (e.g., Ficam Plus, Whitmire PT270). If fumigation is carried out in-house for rodent control, some specialized protective breathing apparatus, tools, signs, and detector sampling tubes and meters, in addition to the fumigant, will be required. It is recommended that the military services contract out such fumigation work to individuals who are trained and licensed by regulatory authorities to do this type of specialized pesticide application.

12.5 Non-residual Aerosol Spraying

Many people have been unpleasantly surprised, travelling on an aircraft to begin a vacation in the Caribbean or in the South Pacific, with the following event. As the plane began its final approach and the passengers were preparing to arrive, a flight attendant walked down the aisle spraying an insecticide aerosol over the heads of the passengers. Alternatively, the exercise may have been done as the aircraft was leaving its embarkation terminal.

Not only is this procedure a relatively 'hit-and-miss' pest control measure, it is poor public relations because most crew and passengers do not appreciate being sprayed with an insecticide. Many airlines recognize this fact but they have little choice because the country of destination may demand that such 'blocks-away' spraying be done to prevent the introduction of unwanted insect pests.

Space spraying does have its place. If an

aircraft is infested with flying insects (e.g., mosquitoes, fruit flies), they must be controlled before the doors are opened. The spraying may take place just before take-off or before landing. Some airlines conduct the spraying just before landing, as if to emphasize that they have to do so and to associate the sometimes offensiveness of the job with the country of debarkation, not with the airline. Some airlines have resorted to injecting an odourless insecticide into the air circulation system, just prior to landing, to meet legal quarantine requirements.

12.5.1 Aerosol Sprays in Passenger Cabins

When required, 'preflight spraying' is usually carried out before air crew and passengers are boarded at the port of departure to kill any insects that may have entered the aircraft while it was on the ramp. The flight deck, passenger, and cargo areas are treated. Also, an aerosol spray is applied to wheel wells, door closures, and other openings.

When required, 'top-of-descent spraying' is usually carried out immediately prior to arrival in a country. This spraying should be limited to the passenger and cargo areas. This spraying destroys any flying insects that may have entered the aircraft during loading or boarding. Cabin air-conditioning does not seriously affect aerosol disinsections (77).

Up until about 1975, most airlines sprayed the cabins of their aircraft with a WHO-approved formulation of pyrethrins and DDT. Depending upon the country being entered, the cabin might be sprayed and the doors kept closed for 2 minutes or so, the passengers then being allowed to disembark, and the cabin being resprayed and kept closed for an additional 5 minutes or so. This was called 'on-arrival spraying'. These double-spray procedures inconvenienced air crews, passengers, and aircraft movements. And. because pyrethrins have a strong odour, researchers searched for better contact sprays.

A number of synthetic pyrethroids, including allethrin, resmethrin, and bioresmethrin, were evaluated (15). Some problems (usually, offensive odours) were encountered and work concentrated on d-phenothrin, an almost odourless material with no apparent harmful effects. A 2% d-phenothrin formulation, tested in the mid-1970's (15, 58, 83), was first approved by WHO in 1977 (78).

12.5.2 Use of d-Phenothrin in Aircraft

In 1979-80, Fons *et al.* (23) conducted studies on the efficacy of d-phenothrin on the Mediterranean fruit flies, melon flies, and Oriental fruit flies. Their findings indicated that 2% d-phenothrin, at an application rate of 10 g/1000 cu. ft., was effective against these pests. Their research led to the evaluation of d-phenothrin for use in aircraft. It was found that this same application rate is effective against a wide variety of flying insects.

It is one thing for an insecticide to be effective against the target pests. It is another thing for it to be acceptable from a health point-of-view. Information on d-phenothrin is available in WHO's (8) report on d-phenothrin (copies are available from the World Health Organization's Distribution and Sales Unit, 1211 Geneva 27, Switzerland, Tel 791-24-76, Fax 4122-788-04-01).

The only potentially harmful effect of d-phenothrin on aircraft components was noted by Russell *et al.* (78). This was when some Qantas aircraft were being routinely double-sprayed with d-phenothrin upon arrival in Australia. He stated that 'in 1978, a problem was raised when electronic equipment components on Qantas B747 aircraft were found to be affected by a residue build-up attributable to the insecticide. A trial was conducted to assess the efficacy of a single spray of 10 grams per 1000 cubic feet; this proved acceptable and the second cabin spray was dropped from the normal disinsection procedure'.

Subsequently, studies showed that in-flight spraying of B747 aircraft worked just as well as when done after landing and before the passengers disembarked (56). However, d-phenothrin does not usually give a quick knockdown or kill of insects. This material takes about 30 minutes to knockdown and kill all the insects aboard an aircraft. As a result, airlines switched to 'in-flight spraying'. D-phenothrin was applied as a single spray, at a rate of 10 grams of aerosol per 1000 cubic feet of aircraft cabin space. The insects were killed during the flight, spraying being done after 'blocks-away' and before final approach, at the crew's convenience.

For example, Air France, like many international airlines, follows the strict World Health Organization 'blocks-away' procedure, applying the aerosol between the time the doors are closed and the aircraft begins to taxi. As proof of compliance, the empty aerosol containers are provided to the quarantine officials upon arrival at the destination.

12.5.3 Use of d-Phenothrin by DND

Currently, some international air carriers in Canada use aerosol formulations of d-phenothrin for aircraft disinsection despite the fact that it is not registered yet in this country. With Agriculture Canada's approval, the U.S. product is purchased and held in bond in Canada and is used aboard aircraft while flying outside Canadian air space. It is not to be used in Canada. For example, Air Canada has taken this approach and it seems to work well.

12.5.4 Aerosol Sprays in Hercules Cargo Areas

Some airlines (e.g., Qantas) use an automatic device, fitted to all B747 aircraft in their fleet, to treat cargo areas (78). Attached to the inside surfaces of the cargo doors, the device is automatically activated upon take-off. The formulation used is a mixture of 2.5% pyrethrins, 2.0% d-phenothrin, and 1.25% piperonyl butoxide (a synergist). Indicators, showing that the aerosol has been released, are visible through the pressure relief hatches.

For most military transport aircraft, aerosol treatments with d-phenothrin are limited to the cargo deck area. The U.S. Air Force has a regulation detailing the procedure to be followed. For a CC130, having a cargo deck volume of 8340 cubic feet, a 2% d-phenothrin aerosol would be sprayed up and down the closed compartment for 1 minute and 30 seconds, keeping the nozzle upward at an angle of 45° and at least 18" from all surfaces.

12.5.5 Aerosol Treatments in Wheel Bays

Insects can survive within the wheel bays of aircraft. Although external tempera-

tures may be as low as -42 to -54°C for aircraft cruising at 10,700 to 11,900 metres, temperatures in wheel wells rarely go below +8°C. Most insects can easily survive these temperatures and low pressures and can then disperse upon arrival in another country.

Because of the build-up of films of grease and oils in the wheel wells, residual treatments would not be effective. Aerosol treatment of these areas of the aircraft, just before take-off, is recommended (74).

12.5.6 Automated Spray Dispensers

Research was carried out on automatic aerosol dispersal systems during the 1930's and 1940's. This type of light-weight apparatus has a central, pressurized reservoir of insecticide, tubular connections to all areas of the fuselage, and is run off the landing gear hydraulics (45, 88). It was designed to emit pre-determined amounts of insecticide into the various areas of the cabin and hold at take-off and/or landing.

The main disadvantage to such a system was the chance of mechanical breakdown. Routine maintenance checks had to be carried out to calibrate and refill the equipment. Because mechanical failure was always possible, a back-up supply of pressurized cans still had to be carried and manually used by crew as necessary.

Although some air carriers have recently expressed an interest in such a system as a possibly less intrusive, more efficient, and less expensive means of in-flight disinsection than air crew using aerosol cans to do the job, no-one seems to be developing such a system for use in modern aircraft.

12.6 Residual Spraying

Residual sprays are those that, after application to a surface, remain on the surface for some time afterwards, killing by contact any insects that move over that surface. Although many insecticides have some residual activity, ranging from a few days to a few weeks, many of them are not suitable for use on or in an aircraft.

Residual treatments can be used to prevent infestations of crawling insects onboard aircraft (4, 6, 17, 18). They have been recommended by WHO several times as part of an aircraft disinsection program. Because aerosol treatments rarely provide control of crawling insects (e.g., cockroaches), residual sprays are usually required to deal with such insects. Residual treatments involve the even spraying of all areas, where insects might feed or seek shelter, with an insecticide that will keep working for up to several weeks or months.

Residual spraying should also be considered where palletized military equipment or U.N. relief supplies have been stored outdoors during a deployment. The pallets are prone to infestation by spiders and other insects. They may also be or become infested with wood-boring insects.

Treating them with a residual spray once per month but, in any case, before re-loading may prevent accidental introductions of pests into the aircraft. In any case, DND should consider the use of pallets made from aluminum or recycled plastic materials as an alternative to the standard wooden pallet.

Despite WHO recommendations, few military or civilian air carriers use residual

treatments on a regular basis. Air New Zealand is exceptional in that it uses Permex 850 (an odourless, water-soluble, permethrin formulation that is registered in that country) to control cockroaches, beetles, moths, and other insect pests on interior surfaces and carpets in its aircraft. Applications of 2% permethrin are made to holds, cabin lockers, under seats, backs of seats, toilets, and other enclosed areas (6, 7).

12.6.1 Advantages and Disadvantages of Residual Spraying

The main advantage of residual spray treatments is that it prevents the development of a wide range of insect problems (6). Other advantages include the fact that such treatments are effective in killing most insects entering an aircraft at foreign airports. Spraying can be carried out during periodic maintenance procedures, in the absence of crew and passengers and with minimal interruption to schedules

However, there are several disadvantages. Sometimes, the spraying is unwarranted because no insects come aboard the aircraft. Sometimes, there is no risk of insect introductions (e.g., domestic flights). Often, some of the treated areas are subject to frequent cleaning (e.g., toilets, galleys), washing away any residual deposits. Also, residual spraying tends to be more expensive than aerosol treatments.

Residual treatment with an odourless insecticide does make good sense in those situations where there is opposition to standard aerosol treatments by air crew and passengers and where there is a high potential for insects aboard a given aircraft. Residual spraying is highly recommended in a situation where an aircraft is deployed to a poverty-stricken or strife-torn country.

A residual insecticide formulation used in aircraft must meet strict criteria:

- Non-corrosive to metal and plastic.
- Non-staining to carpet and seat fabric.
- Safe and easy to apply.
- Good residual effectiveness (i.e., several months)
- Effective against a broad range of insect pests.

12.6.2 Residual Sprays Registered for Use in Aircraft in Canada

The products that are currently registered for use in aircraft in Canada are as follows:

- Ficam Wettable Powder (80% bendiocarb).
- Ficam Dust (1% bendiocarb).
- Ficam Plus Synegized Pyrethrins Wettable Powder (29.45% bendiocarb/3.06% pyrethrins).
- Whitmire PT 240 Perma-Dust (20% boracic Acid).
- Whitmire PT 270 Dursban (0.5% chlorpyrifos).
- Bugcon Super Space & Contact Residual Insecticide Solution (0.7% pyrethrins/4.0% piperonyl butoxide).

Each country will have its own list of approved products. Interested persons should consult with their national pesticide registration officials to determine which pesticides they can use in their aircraft.

12.6.3 Use of Permethrin

According to WHO recommendations, permethrin should be applied as a residual deposit to cover all surfaces at a rate of 0.2 grams active ingredient per square metre (18). Carpet is given a higher application rate (i.e., 0.5 grams/square metre). Such treatments have been shown to remain effective for up to 8 weeks (72).

Follow-up treatments with permethrin need not be as high. Aircraft that have been previously treated at the above rates can be treated subsequently at 0.2 grams per square metre on carpets and 0.1 grams/square metre on other surfaces (5).

12.6.4 Use of Bendiocarb

Because cockroaches may develop resistance to an insecticide if it is used repeatedly, rotating the use of insecticides is advised. Every second insecticide application will then use an insecticide from a different class of insecticide. If permethrin is chosen, a good material with which to rotate it would be bendiocarb (e.g., Ficam). WHO has recommended bendicarb for use against all crawling insects. When Ficam W (a wettable powder formulation) is applied at a rate of 0.6% to the point of run-off, it will persist for 3-6 months.

Bendiocarb, in addition to having a special clearance from the U.S. Environmental Protection Agency for use against a wide range of insect pests on aircraft, is specifically recommended for use to combat the spread of insects that enter an aircraft via wheel wells and cargo holds (13). Moreover, it is the only residual insecticide recommended by WHO for use against cockroaches on aircraft.

The advantages of using a residual insecticide with this relatively long residual life are that it can be carried out as part of the periodic maintenance procedure and in the absence of crew and passengers. This formulation has no odour, is non-staining, and leaves no visible deposit on most surfaces.

12.6.5 Precautions with Residual Sprays

Prior to any residual application with a new material, the preventive medicine technician should contact the manufacturer of the insecticide and discuss the specific products and formulations that will be used. The use of corrosion-tested, low-volatile insecticides and strict adherence to label directions and precautions are vital to aircraft pest management. *Never apply a residual insecticide in the flight deck area or directly on sensitive electronic equipment located elsewhere in the aircraft.*

Base management personnel can advise pest management technicians about an aircraft's presence or absence and its scheduled maintenance. All aircraft need periodic maintenance. Major pest treatments can be timed to coincide with those maintenance operations when the aircraft is grounded for several days. Insecticidal applications, especially for serious infestations, are most effective when they are made during a major overhaul of the aircraft and when the cabin installations are dismantled and seating is removed.

Different combinations of approved insecticides may be used. In the toilet areas, bendiocarb, chlorpyrifos or diazinon sprays could be used. Around seats and the pas-

senger area (including the food handling area of the aircraft), many workers recommend bendiocarb.

In the cockpit area, most workers only use an insect bait or trap, if anything. *Never use an insecticide in, on, or near electronic equipment.* The aircraft's safety is paramount.

The use of an insecticide formulation that has a strong chemical odour should be avoided. Odour is difficult to judge. What may be 'relatively odourless' to the seller might have 'a strong chemical odour' to the buyer. Also, different formulations of the same active ingredient may differ in their odour. The best way to check is to order a sample and determine whether or not it is acceptable before committing to using it.

12.6.6 Residual Treatments of Flight Decks

Only permethrin (2%), in a special totally freon-based aerosol, can be safely used to treat electrically-sensitive areas such as a flight deck (72).

12.6.7 Residual Treatments of Floors and Walls

Insects tend to rest on floors and walls, especially in quiet, dark corners and in cracks and crevices where they are seldom disturbed and where food may accumulate.

Generally, residual treatments to carpeting stand-up well to vacuuming but they may fail sooner in areas with high foot traffic (aisles) or rigorous cleaning (toilets, galleys).

12.6.8 Residual Treatments under Floors

In transport aircraft with metal floor panels, there are usually openings along the sidewalls to facilitate air movement. It is through these openings that both spilled food and pests may pass freely. These areas must be cleaned frequently to prevent any accumulations of food that will attract pests, especially insects and rodents.

When it is both difficult and expensive to remove these panels on a regular basis, residual treatments with an insecticide like permethrin or bendiocarb will prevent any insect pest problems from developing for at least one month.

However, there is some suggestion in the literature that some insecticides (e.g., permethrin) lose their efficacy on painted surfaces within a few days (17). Thus, choosing a product that would be suitable requires testing the insecticide when used on the particular paints used to cover such surfaces.

Although not registered in Canada nor, to the author's knowledge proven safe for use in aircraft, there is an American product which is basically an insecticide-paint mixture. Called 'Super IQ' (manufactured by Nufarm Ltd., St. Joseph, MO), it is a contact insecticide and paint that is painted on floors, walls and ceilings of structures to give effective, economical, and long-term insect control (up to 2 years). It provides a durable, washable, odourless surface within 24 hours.

If this product is ever developed for use in aircraft, it would have excellent benefits for transport aircraft that are used to carry raw food materials.

12.6.9 Residual Treatments of Sky-walk to Aircraft Connections

In some situations, an application of a residual insecticide to the surfaces of sky-walks may be warranted to kill any deplaning insects that may have escaped earlier attempts to kill them. Although, if aircraft disinsection has been carried out by trained and diligent crew using standard procedures, this may seem unnecessary, it would tend to minimize the risk of insect introductions where there was poor attention to aircraft disinsection.

12.7 Use of Insecticidal Baits

Insecticides, especially when placed in tamper-proof bait stations, play an important role in pest management and need to be customized to the particular pest and the given situation. The use of insect growth regulators (e.g., hydramethylnon) and low-toxicity baits (e.g., boric acid) are effective pest management methods for certain pest species (34).

Baits are just starting to be used in aircraft for cockroach control. Usually, the baits are placed in storage lockers, galleys, toilets, and other warm, moist areas where cockroaches seek shelter. Most bait stations are small, adhesive-backed, tamper-proof, plastic containers. After placement, they remain effective for up to a month or so. They pose no risk to crew or passengers.

Bait stations play a valuable role in insect pest management programs aboard military aircraft. Whereas other methods may be more suitable and practical for such transport aircraft as the CC130, bait stations could be used to advantage in passenger and surveillance aircraft (e.g., Airbus, P3 Orion, Nimrod). However, if such bait stations are used, the member of the aircrew placing and maintaining the baits must keep meticulous records on each placement and must avoid any placement where the bait might come loose and lodge in a sensitive control.

12.8 Fumigation

Fumigation is the preferred method to eradicate severe infestations of insects, soil organisms, and any rodents or snakes sighted aboard an aircraft. The gas, unlike aerosol and residual applications of a pesticide, can penetrate *all* areas. WHO makes no reference to aircraft fumigations. Detailed specifications and procedures (2-4) are given for the use of aerosols and residual sprays aboard aircraft but no recommendations are given on aircraft fumigation.

With aerosols, in particular, passengers and crew may be confined in a closed environment with no opportunity to escape the odour of some insecticides. This is especially true during in-flight applications. Because many people mistakenly associate chemical odours with danger, any lingering odours may cause passengers to complain to the carrier about pesticide exposure. Fumigation, because it is done in the absence of people, resolves this problem.

12.8.1 Fumigation with Methyl Bromide

As a matter of flight safety, aircraft manufacturers want to know what chemicals their customers apply in their aircraft. Some manufacturers may object to the use of methyl bromide because the chemical, *in its liquid form*, can etch certain metals,

including aluminum alloys. However, there is no documented evidence that this fumigant, *in its gaseous form*, will damage these alloys. Pure methyl bromide *must* be used, not the more corrosive methyl bromide-chlorpicrin mixture that is commonly used to fumigate buildings.

Reference is made to the possibility that damage to aircraft components may occur. However, no detailed assessment or concrete evidence that gaseous methyl bromide will damage planes has been published. Although methyl bromide is very effective, in the hands of competent people, some aircraft manufacturers refuse to endorse its use in their aircraft. A summary of the methyl bromide/aircraft controversy is given by Meyers and Smith (64).

To minimize any risk that liquid methyl bromide might remain in an aircraft, the fumigation must be carried out during the summer months in Canada. If fumigation is required during the winter months, the interior of the aircraft must be maintained at room temperature (minimum of 10°C).

Many pest management personnel prefer methyl bromide over conventional insecticide treatments because it is a quick and sure way to eliminate a pest and because the aircraft makes an excellent fumigation chamber. The risk of the fumigant leaking is minimal. Nevertheless, pest management personnel in some countries are denied this effective pest control tool because of unsupported and unconfirmed theories.

Ironically, a number of countries (including Australia, Japan and New Zealand) require that aircraft parts, such as jet engines and electrical assemblies, be fumigated with methyl bromide to kill any wood destroying insects that might have infested the shipping crates. Therefore, many commercial aircraft are regularly exposed to this fumigant.

Methyl bromide is a valuable tool in the aircraft disinsection in many countries. Almost all types of aircraft (including the Boeing 707, 727, 737, DC9, BAC 1-11, and Concorde) have been successfully fumigated. Special fumigation procedures, complete with unique equipment designed for the use of methyl bromide on aircraft, have been developed by some pest management companies in several European countries (e.g., Rentokil Environmental Services).

Phosphine, a different fumigant, must not be used in aircraft because corrosion may occur, especially in conditions of high temperature and high relative humidity.

12.8.2 Fumigation Procedures

A modern pest control firm might have the following basic procedure for the fumigation of aircraft: i.e.

- After an aircraft is empty, cleaned, and parked well clear of buildings and other aircraft, the fumigation crew arrive. The technicians then set up their specialized fumigation equipment.

- The service technicians first perform a security check to make sure that there is no-one left on board. They place warning signs around the aircraft stating 'Keep away. Fumigation in progress'. They then place 5 kg cylinders of methyl bromide throughout the plane. Pure methyl bromide must be used; not a methyl bromide

formulation with a chlorpicrin additive. The latter is essentially picric acid and it has a corrosion potential.

- Each pre-weighed cylinder of fumigant may be connected to its own small computer, which, in turn, may be connected by a network to the other computers (e.g., 6 sets per 747). Each cylinder is fitted with a 60 psi regulator and an atomizing jet that controls the gas's release and ensures that there are no free droplets of the fumigant.

- When the cylinders are set and ready to go, the technicians do a final check and close all but one of the aircraft's doors. As the technicians turn on each computer, a green light on top of the unit lights up. When all computers have a green light, the countdown starts. The technicians then disembark and seal the plane. After 10 minutes, the computers open the valves on the fumigation cylinders.

- The computers shut down the entire system after another 20 minutes, when the tanks are empty. The plane is left sealed to give the fumigant time to do its job.

- After leaving the aircraft sealed for sufficient time (e.g., 2 hours for rodents and 4 hours for cockroaches), the technicians, wearing self-contained breathing apparatus (SCBA), turn on a mobile air conditioning unit, open all of the doors and re-enter the plane. They then shut-down the computers and carry out their equipment.

- Gas checks are made to ensure the fumigant has cleared the aircraft, especially areas known to have low air movement. Air can be rammed in to the aircraft if necessary. It may take 30-45 minutes for all of the gas to clear all areas of a large aircraft, including foam seats and insulation batts. Once the gas level is below the acceptable threshold of 1-2 ppm, the fumigators will issue a clearance certificate and remove the warning signs.

Thus, a large aircraft might be treated and clear for use within 2.5-5 hours, depending on the target pests. Airlines appreciate the effectiveness and expediency of methyl bromide fumigations. Individual planes have been fumigated more than 50 times without incident.

Rentokil Environmental Services (U.K.) has prepared an in-house Fumigators' Manual that discusses these procedures in greater detail. Should an air force consider training members of its own staff in aircraft fumigation, Rentokil would seem to be the best choice to provide the necessary training. Alternatively, should an air force choose to contract out any fumigation work required, the draft contract specifications should be reviewed by someone who is very familiar with the specialized requirements of this type of work.

Despite the worldwide success of methyl bromide fumigations, some aircraft manufacturers still refuse to endorse its use. Thus, research into better alternatives continues. Some work is being done using carbon dioxide as a synergist with methyl bromide (9) as part of the worldwide move to reduce methyl bromide emissions. Although the technique seems to work well in some situations (e.g., structural fumigations for termite control), it has not been widely used commercially in aircraft fumigations. A notable exception is the use of this technique in Norway by Rentokil Norge in MD80's and DC9's. This firm claims good success with this mixture.

12.8.3 Fumigation with Carboxide

Carboxide has been used as an aircraft fumigant in Canada by Air Canada and other air carriers. Its current status for use in aircraft is uncertain. It was used for many years before its use was suspended in Canada. There is a rumour that it soon may be allowed in aircraft again. In their Materials and Process Manual, Air Canada has a section on aircraft fumigation, using carboxide gas. According to Air Canada, fumigation is only deemed necessary when standard aerosol and residual spray treatments fail to control an insect problem or when a rodent is sighted by the air crew. Until such time as the status of carboxide for aircraft fumigation is settled, the Canadian Air Force will use methyl bromide, when and where necessary.

12.9 Records of Pesticide Applications

According to the latest Canadian Treasury Board regulations on pesticide safety and application, records must be made and kept of all pesticide applications for 30 years. The records become very important in the event of a misapplication or a pesticide poisoning investigation. Records must be made available upon request of the appropriate federal safety and health officials.

Record sheets should be made up to record the following items of information:

- Date and time of pesticide application.
- Pesticide that was us.
- Pesticide formulation used.
- Application rate used.
- Type of equipment used.
- Aircraft treated (tail number, specific areas treated).
- Target pest(s).
- Name of the pesticide applicator.

These record sheets should be filled in and signed by the preventive medicine technician and become part of that aircraft's records. Copies of all completed forms should be kept in a central archive for possible future reference.

12.10 Safety Considerations

During the mid-1970's, concerns about the effects of insecticides on human health and the environment were at the forefront. There were also growing concerns about the increasing risks of spreading undesirable insects. The key concerns centred on the following:

- Effects of aircraft disinsection on the health of crew and passengers.
- Effects of propellents used in insecticide aerosols on the ozone layer.
- Development of resistance of insect pests to insecticides.
- Increasing number of countries where civil disturbances have permitted the build-up of pests.
- Development of techniques that could be used in the absence of air crew and passengers.
- Difficulties associated with the analysis of a growing body of data on aircraft disinsection.
- Observations of more small aerosol spray droplets present than thought (14).

Public concern over chemical use is spread by the news media and environmental pressure groups who portray all pesticides as being highly poisonous and hazardous.

If pesticides are critically examined in isolation, it is easy to condemn them and their use. Viewed in relation to the many other domestic and commercial products that are available, that are often as or more harmful, and that are readily used by most people, pesticides could be in the same category as many bathroom cleaners, disinfectants, paint thinners, and personal hygiene products.

The question of safety always arises, whether considering an aerosol treatment, a residual application, or a fumigation. Generally, if label precautions and directions are followed, the products that are currently recommended for aircraft disinsection have a wide toxicological safety margin when carefully applied by trained and diligent staff.

A technician carrying out pest control must gain the cooperation of management, air crew, maintenance staff and other service contractors to ensure that all work is done safely. Cooperation is essential for implementing most IPM measures (64).

Technicians must also ensure that all required records are completed and maintained in accordance with federal directives. Without careful planning, there will rarely be enough time to service a fleet or to properly manage pest populations in a safe and effective manner.

12.11 Aircraft Integrity

Pesticides recommended for use in aircraft must comply with the safety requirements of the International Civil Aviation Organization. Products used must be non-flammable, free from human toxicity risks, and non-injurious to materials used in aircraft construction (2). The materials currently recommended by WHO for aircraft disinsection through the use of aerosols and residual materials are considered to meet these standards.

12.12 Research into Better Spray Equipment and Insecticides

Investigations into better spray equipment and insecticides for aircraft disinsection was increased in the 1970's (81, 84, 97). Test insecticides were applied as aerosols or as dusts, propelled by CO_2 gas. Initially, insects were released into a semi-trailer used to simulate an aircraft cabin. Problems with recapturing the test insects led to the subsequent use of caged insects. Extensive tests were also conducted in commercial training flights.

During these developments, some of the new synthetic pyrethroids (e.g., resmethrin) showed promise. Resmethrin was rejected because it decomposes in sunlight (UV light) to form phenylacetic acid, a compound that smells like urine (102). A 2% d-phenothrin formulation, propelled by freon, was finally selected as the best material to use (8). Kerosene was excluded as a medium because kerosene aerosols, when inhaled by rabbits, cause lung damage.

Sullivan worked with WHO to test his formulations. Sullivan *et al.*, (97) endorsed the 1961 WHO recommendation for disinsection of the cabins at 'blocks-away': i.e., disinsection as the blocks are pulled away from the wheels of the airplane and it taxis to the take-off point.

Dusts were also tested (36, 82, 97, 104). Although the insecticidal dusts were shown to be effective, they were not favoured by airline pilots.

Based on the declining number of research papers written on this topic in the 1980's and 1990's, this research field has become stagnant. Both of the key agencies involved, WHO and USDA, have more or less dropped out of the field since the early 1980's, probably as a result of the decline in the world economy.

One encouraging observation is that WHO plans to hold a conference on aircraft disinsection in late-1995. Experts from around the world will review the topic and hopefully more research into better and safer alternatives will be encouraged.

Based on this author's review of aircraft disinsection, further research needs to be conducted on the following topics:

- New insecticides, with less risk to the health of air crew and passengers.
- Better methods for the formulation and delivery of these new insecticides.
- Evaluations of the newly-developed flurocarbon-free aerosol propellents.
- Efficacy evaluations of residual insecticides in aircraft wheel wells.
- Efficacy evaluations of residual insecticides on painted surfaces.
- Evaluations of ultralow volume (ULV) insecticides in transport aircraft.

13. Summary

The basic principles of a good military aircraft disinsection programme are:

- Thorough inspections help pest management personnel determine the need for pest management. With a monitoring and a preventative program (including thorough and regular vacuuming of the aircraft) in place, pest management technicians can, if necessary, apply spot treatments of a residual between flights with little if any impact on scheduling. During the night, when most aircraft are available for this type of work, one technician can easily treat several transport aircraft with a residual insecticide. Obviously, a close rapport between air crew, maintenance staff, and preventive medicine technicians must be maintained to solve any pest management scheduling problems.

- Because of their mobility, aircraft are more difficult to treat than permanent facilities. For example, some aircraft are away from their base for long periods of time. Procedures must be in place for regular disinsection by preventive medicine technicians before transport aircraft are deployed abroad.

- A maintenance escort must be available when any spraying is done to answer questions on the locations of sensitive electronic equipment, to remove and replace wall panels and floor panels, and to supervise the placement of any bait stations and sticky traps placed aboard the aircraft.

- A preventive medicine technician must accompany any contracted pest management technician during service to ensure that proper records are kept of insect monitoring and treatment and that proper safety procedures are being followed. To reduce liability, non-essential staff must *not* be present during the application of insecticides.

- If pest management services are contracted-out, the pest management technician must be available 24 hours a day, 7 days a week, in case of an emergency.

- Trained air crew must carefully carry-out 'blocks-away' or in-flight aerosol treatments to meet the health and quarantine requirements of both home and foreign authorities during certain specified international flights.

- Records must be kept of all aircraft disinsections, including aerosol applications, residual treatments, and fumigations to meet federal occupational health requirements.

14. Conclusions and Recommendations

Based on this review of the regulatory and technical aspects of aircraft disinsection, the author recommends that following steps be taken to modernize NATO Nations Air Forces existing policy:

1. Establish a cooperative relationship between the Chief of Air Force Medical Services, the Pesticide Regulatory Agency, and the Plant and Animal Health Agencies of each Nation's Agriculture Department.

2. Clearly identify the responsibilities assigned to air crew, cabin crew, maintenance personnel, and the medical authority and to any civilian contractors who service the aircraft (see also below).

3. The aircraft commander, whether military or civilian, must be responsible for ensuring that the aircraft is clean and free of pests and soil and that the air crew watch for and report any pests that are present. Good housekeeping must be the first line of defence against pests. Physical removal of pests must be the next step in pest management. Thorough vacuuming (followed by proper disposal of the vacuum bag) is the best way to remove most insect pests. In transport aircraft deployed for bulk food deliveries, the central row of floor panels must be removed and the area underneath inspected and vacuumed as necessary at the end of the delivery program, before returning home. These tasks must be the responsibility of the air crew.

4. The equipment currently used for vacuuming is inadequate. An explosion-proof canister vacuum and accessories (e.g., Hako Minuteman) must be purchased, be kept with the aircraft, and be used by air crew both at base and on deployment outside the country.

5. An alternative vacuum is a back-pack vacuum called the 'Li'l Hummer'. Much more portable, it is not currently approved for aircraft but is widely used and highly recommended by the pest control industry. Steps must be taken to evaluate this equipment and to obtain approval for its use.

6. Passenger, surveillance, and transport aircraft must be routinely monitored for insect pests using box-shaped, low-profile, sticky traps. Although this should normally be the responsibility of the preventive medicine technician, the task must become the responsibility of air crew when a preventive medicine technician has not been deployed out of country with the aircraft. When this occurs, the preventive medicine technician must provide traps and instructions to the air crew involved prior to the aircraft being deployed.

7. Where there is a legal requirement to disinsect an aircraft prior to entry in a foreign country or return home, the non-residual insecticide of choice is 2% d-phenothrin. This insecticide can be purchased from the U.S.A. (EPA Registration No. 39398-1), as is done by some commercial carriers. An alternative non-residual insecticide is the pyrethrin aerosol (0.7% Pyrethrins/4.0% Piperonyl Butoxide, PCP Registration No.20745).

8. The recommended technique for non-residual spraying is the 'blocks-away' procedure. For operational reasons, 'top-of-descent' or 'on approach' procedures are also acceptable.

9. When and where necessary, residual spraying should be carried out. If non-fighter aircraft are to be deployed for 1-6 weeks outside North America, residual spraying must be done before leaving.

10. To prevent insecticide resistance among the target pests, the insecticides of choice must be used in rotation whenever possible. The insecticide of choice is bendiocarb. It is registered for use in Canada (Ficam Plus Synegized Pyrethrins Wettable Powder, a 29.45% bendiocarb/-3.06% pyrethrins formulation, PCP Registration No. 20105). The second insecticide of choice is permethrin. If, like d-phenothrin, it can only be used outside a country, it will be necessary to purchase product from the U.S.A. and hold it in bond (as is done by some commercial carriers). Until permethrin becomes available for use, bendiocarb must be used in rotation with Bugcon Super Space & Contact Residual Insecticide Solution, a 0.7% pyrethrins/4.0% piperonyl butoxide formulation, PCP Registration No. 20745).

11. Permission to purchase and hold in bond the insecticides (i.e., d-phenothrin and permethrin) must be obtained from the country's equivalent of Customs and Excise Canada. All of the insecticides named above must be assigned NATO stock numbers and be placed in the supply system.

12. When aircraft fumigation is required, the insecticide of choice is methyl bromide. This fumigant is a rigidly-controlled pesticide that kills both insects and rodents aboard aircraft. Fumigation services must be contracted out to licensed fumigation specialists and done under the supervision of the preventive medicine technician and the aircraft maintainer.

13. Spray records must be kept in accordance with a country's federal directives. Each aircraft disinsection must be recorded and kept with the aircraft's records.

14. Completed copies of the aircraft disinsection record form must be provided to the Chief of the Air Force Medical Services. When an aircraft is at its base unit, the responsibility for record-keeping and provision of copies must lie with the maintenance and preventive medicine staff. When an aircraft is away from its home unit, the responsibility for record-keeping and transfer of records (to the home unit's maintenance and preventive medicine staff and to the Chief of the Air Force Medical Services) must lie with the aircraft commander.

15. Preventive medicine technicians must be fully trained in (a) the safe storage, handling and use of all of the insecticides mentioned above, (b) in the proper cali-

bration use of the spray equipment used in aircraft disinsection, (c) in aircraft fumigation methods and materials, and (d) in the national and international regulations and directives governing aircraft disinsection.

16. Aircraft garbage brought back to a home country must be collected, sealed in tagged plastic bags, and disposed of according to current national regulations by the air crew.

17. For those Nations with no amnesty bins, discussions must be carried out with quarantine officials to determine the feasibility and logistics of setting up and operating amnesty bins at all points of entry.

PART C. DRAFT ADMINISTRATIVE ORDER ON AIRCRAFT DISINSECTION FOR THE CANADIAN AIR FORCE

The following text is the final draft of an administrative order on aircraft disinsection for the Canadian Air Force. It may serve as a model for other NATO Air Forces.

Aircraft disinsection - Responsibilities and Procedures

Purpose

1. This order prescribes the disinsection of Canadian Forces aircraft for air crew, maintenance staff, preventive medicine technicians, and passengers as it applies to international flights.

Definitions

2. In this order, several technical terms are used. They are defined below:

Disinsection refers to the steps taken to prevent and control disease vectors and pests of agriculture and forestry that may be present in an aircraft.

Disease vectors may include both insects (e.g., mosquitoes, house flies) and rodents (e.g., rats, mice).

Pests include any disease vectors that are present in locations where they are not wanted. Depending on the organism involved, a pest may be simply a nuisance or it may cause serious damage to either other life or to property.

Pesticides include any insecticides and fumigants intended for killing, controlling or managing weeds, viruses, bacteria, fungi, mites, spiders, ticks, insects, birds, rodents, or other plants or animals considered to be pests.

Aerosol sprays are contact insecticides that will usually kill any flying or crawling insects that come into direct contact with the fine spray droplets before they evaporate, usually within 5-10 minutes. Once dry, the residues on treated surfaces have little, if any, effect on insects later crawling over or resting on these surfaces.

Residual sprays, on the other hand, are applied to surfaces like walls and floors to kill crawling and resting insects. Once dry, the residues remain effective for varying periods of time, depending on how heavily the areas are used, cleaning frequency, moisture and heat conditions, and the insecticide used. Some residual insecticides may be active on treated surfaces for up to 60 days.

Fumigants are gases (formed from volatile liquids, gases or granules) that kill rodents, insects, spiders, nematodes, bacteria, fungi, and plants (including seeds, roots, rhizomes). They are usually applied in a sealed enclosure of some kind (e.g., an aircraft) or under a tarpaulin or plastic sheet covering a structure or the soil.

Fumigation is the release of a pesticide so that it reaches the target organism in the vapour or gaseous state. Fumigants have no residual activity.

General

3. Aircraft proceeding to a foreign airport

must conform to the medical and quarantine requirements applicable to that country regarding aircraft, air crew, passengers, baggage and cargo.

4. Transport aircraft carrying bagged food materials are most prone to infestation with pests. Steps shall be taken to prevent, to monitor for, and to control these pests using available non-chemical and chemical options. All members of the air crew shall be aware that insects may fly into the aircraft through open doors and windows and that rodents may enter using ladders, ramps, and other devices. Bats and birds may fly into transport aircraft through open doors or windows.

5. Passenger aircraft (e.g., Airbus) tend to become infested with cockroaches, especially in the galleys. These common insect pests are usually brought aboard in airport food catering carts. Occasionally, a rodent may enter a parked aircraft, with steps left in place and doors open. However, they more commonly enter with cargo.

6. Departure lounges for passengers leaving the country shall also contain information on the importance of not returning to Canada with illegal materials that may pose a quarantine risk. This public education exercise may prevent some people from placing themselves in a situation where they must either discard, declare, or smuggle materials that may contain pests. In most countries, landing passengers must sign a declaration form which, in part, states that they are not carrying any plant or animal materials. If they declare that they do have such materials, they are routinely inspected by an agricultural quarantine official. Quarantine officials at many airports report that these measures have been successful in reducing the chances of introducing pests through ignorance of the consequences. Military personnel, including both air crew and passengers, shall be briefed on the importance of these rules and warned of the consequences if they are ignored.

7. Pest infestations in fighter aircraft are rare. These aircraft seldom become infested with pests unless they are parked in areas of high pest infestation. Infestations in surveillance aircraft are somewhat more common because they usually have galleys and insect pests may be brought aboard with food. Maintenance personnel will immediately report any pest problems found during periodic maintenance to the preventive medicine technician who will take action the problem.

8. Because the food preparation areas of many foreign food service establishments, especially those not associated with an international airport, lack proper hygiene procedures, both air crew and passengers shall be advised not to bring personal items of food (including meat, fruit, vegetables) on board. Only food provided by the CF logistic system shall be consumed. There is also a risk that food and food packaging from foreign food service establishments may be contaminated with insect pests.

9. Aircraft returning to Canada from a foreign airport must conform to all applicable Canadian medical and quarantine regulations regarding the aircraft, air crew, passengers, baggage and cargo.

10. Agriculture Canada's Plant and Animal Health officials have the responsibility for inspecting aircraft, passengers, baggage,

and cargo for microbial, insect, and vertebrate pests which may pose a threat to Canadian agricultural and forestry industries.

11. Preventive medicine technicians, air crew, and maintenance staff share responsibilities for aircraft disinsection. These responsibilities may vary, depending on whether the aircraft is deployed in a foreign country (with or without a supporting preventive medicine technician), leaving for a country with specific quarantine requirements, leaving a country with disease-carrying mosquitoes, or preparing to return to Canada. These responsibilities are outlined below (Table 1). Aircraft commanders have the responsibility for monitoring aircraft for pest infestations. In accordance with Canadian Forces Administrative Order (CFAO) 34-46, preventive medicine technicians have the responsibility for applying residual sprays or supervising a civilian contractor who applies sprays to aircraft. In accordance with CFAO 55-28, air crew have the responsibility for applying insecticide aerosols, to meet foreign and Canadian quarantine requirements, for all aircraft and for ensuring that any soil and grain spillage is cleaned up promptly in any transport aircraft. While carrying out their work, maintenance staff must report any pest sightings or accumulations of soil or spillage to the senior medical representative who will, in turn, request direction from the Command Surgeon Air Command.

Cleaning Procedures for Aircraft

12. The following applies to all fixed- and rotary-wing aircraft when used for the transportation of food materials in foreign countries. Waste food materials, spilled from previous consignments of grain and lentils, must be swept or vacuumed up from the flight deck, cargo hold, toilet areas, galley, and lockers on a weekly basis and before departure from the country where the food aid program took place.

13. All items of cargo, including pallets, must be examined for pests and accumulations of dirt. Any infested or dirty materials must be thoroughly cleaned before they are loaded onto the aircraft.

14. Examine and clean, as necessary, any items of cargo, including spare aircraft parts and equipment, that were unloaded from the aircraft upon arrival before reloading them onto the aircraft. All waste materials, including vacuum bags, shall be sealed in plastic garbage bags and disposed of according to local guidelines before departure.

15. If the aircraft must depart before it or the cargo is thoroughly cleaned, the aircraft must be cleaned immediately upon arrival back in Canada. If done in Canada, all waste materials, including the vacuum bags, shall be sealed in plastic garbage bags and disposed of in strict accordance with federal plant and animal health regulations.

Pest Monitoring Procedures for Aircraft

16. Transport aircraft shall be monitored for cockroaches and other crawling insect pests on a regular basis. Other types of aircraft will be monitored in response to sightings by air crew. While deployed in a foreign country, the preventive medicine technician shall, in cooperation with air crew, inspect the aircraft on a monthly

basis for accumulations of soil and food and for evidence of pests. In the absence of a preventive medicine technician, these inspections shall be done by the air crew.

17. The monitoring tools and supplies provided for the preventive medicine technician shall include an explosion-proof flashlight, zip-lock bags (18 cm x 20 cm x 2.7 mils), tweezers, rubber-stoppered vials, and sticky traps (including string and a paper punch needed for sub-floor placement of traps). He/she may also require the use of the vacuum cleaner that is assigned to the transport aircraft. He/she should also be issued with a hard hat and ear protectors.

18. Evidence of accumulations of soil and food on the upper surfaces of floor panels will be obvious. The aircraft commander shall ensure that the centre row of floor panels shall be lifted prior to final loading and departure for Canada and that the sub-floor areas are examined for dirt and spilled grains. These spilled materials may include weed seeds and microorganisms. Spilled grains can be highly attractive to grain-destroying insects, mice, and rats. The weed seeds, microorganisms, and insects all pose a risk to Canadian agriculture. Accumulations of rotting, organic matter in the belly of the aircraft may be corrosive to aluminum and other metal components. The rodents, because of their gnawing habits, may damage electrical components of the aircraft and, thereby, seriously threaten crew and passenger safety.

19. The preventive medicine technician, in cooperation with air crew, shall place small, cardboard, box-shaped, low profile, sticky traps below the floor panels of the CC-130. These shall be left in place, secured on a short length of string, to monitor biweekly for food pests. In the absence of a preventive medicine technician, these traps shall be monitored on a biweekly basis by the air crew for the duration of the tour.

20. Evidence of an infestation in any type of aircraft may include the following:

Nuisance Flies - check window ledges for crawling or dead house flies and blow flies.

Mosquitoes - check window ledges for dead and dying mosquitoes.

Maggots - check any food garbage aboard the aircraft.

Cockroaches - check recesses of galleys and food storage areas. Strategically placed cockroach traps, examined biweekly, will reveal their presence in galleys. Cockroaches like warm, moist areas with food nearby. Any suspected leaks in water-holding tanks or pipe joints shall be fixed immediately.

Ants, bees, and wasps - check garbage containers and window areas, including flight deck.

Grain Insects - check accumulations of spilled grains on and under floor panels.

Moth Eggs - check exterior surfaces of fuselage.

Spiders - check dark, secluded recesses of hold and of cargo, especially pallets, for webbing.

Rodents - the presence of faecal pellets

left by mice or rats or a sighting by air crew. Any sign or sighting of a rodent aboard an aircraft must be reported immediately to the preventive medicine technician or the senior medical officer.

Disinsection Procedures for Aircraft

21. In accordance with CFAO 55-28, to prevent the transmission of disease by live insect vectors and to reduce the threat of soil and insect pests to agriculture and forestry, all aircraft departing from the following countries for Canada shall be disinsected with the pesticide specified in para 25-27 below:

- Afghanistan	- South Africa
- Angola	- Bangladesh
- Benin	- Bhutan
- Birmanie (Myanmar)	- Botswana
- Brazil	- Brunei Darussalam
- Burkina Faso	- Burundi
- Cameroon	- China (Shanghai)
- Colombia	- Comoros
- Congo	- Ivory Coast
- Djibouti	- Ethiopia
- Gabon	- Gambia
- Ghana	- Guinea
- Guinea Bissau	- Equatorial Guinea
- Guyana	- French Guiana
- Solomon Islands	- India
- Indonesia	- Cambodia
- Kenya	- Liberia
- Madagascar	- Malawi
- Mali	- Mozambique
- Namibia	- Nepal
- Niger	- Nigeria
- Uganda	- Pakistan
- Panama	- Papua New Guinea
- Central African Rep.	- Laos
- Rwanda	- Sao T.-Principe
- Senegal	- Sierra Leone
- Somalia	- Sudan
- Sri Lanka	- Surinam
- Swaziland	- Tanzania
- Chad	- Thailand
- Togo	- Vanuatu
- Viet Nam	- Zaire
- Zambia	- Zimbabwe

22. In addition, the interior areas of all transport aircraft returning to Canada shall be thoroughly cleaned and disinsected prior to departure. Any cargo and/or aircraft maintenance equipment that was temporarily used or stored in any foreign country shall be thoroughly cleaned and disinsected before it is loaded onto the aircraft.

23. Aircraft entering a foreign country shall be disinsected in accordance with the requirements of the country concerned. Currently, the following countries require that all flights be sprayed enroute or immediately upon arrival:

- Antigua.	- Honduras.
- Argentina.	- Jamaica.
- Australia.	- Mexico.
- Barbados.	- New Zealand.
- Bolivia.	- Nicaragua.
- Brazil.	- N. Marianas Islands.
- Chile.	- Panama.
- Columbia.	- Peru.
- Costa Rica.	- St. Lucia.
- Ecuador.	- Sint Maarten.
- Grenada.	- Trinidad.
- Guam.	- Venezuela.
- Guatemalia.	

24. Subject to international requirements, the aircraft commander shall ensure that disinsecting is carried out immediately before the last take-off when leaving a country listed in para 21 and 22 for Canada or,

when departing for countries listed in para 23, during flight, preferably 'top of descent'. The preferred method to be used is the 'blocks-away' procedure, an internationally recognized method of aircraft disinsection recommended by the World Health Organization. The object is to kill all insect pests present in an aircraft just before departure. 'Blocks-away', internal spraying is done immediately after the doors are closed for take-off. External spraying (see para 25f below) must also be carried out, just before the aircraft doors are finally closed. 'Top of descent' spraying is done to kill all insect pests present in an aircraft just before arrival in the countries listed in para 23. In accordance with Treasury Board requirements, records shall be kept of all aircraft disinsections.

25. 'Blocks-away' disinsection shall be done by the air crew under the direction of the aircraft commander when leaving a foreign country as follows:

a. The insecticide to be used is 2% d-phenothrin, which is supplied in hand-operated aerosol cans.

b. The aerosol dispensers shall be serially numbered and the serial numbers entered on the Health portion of the Aircraft General Declaration Form. The empty cans must be retained after use and, upon arrival at country of destination, will serve, together with the entries on Health part of the Aircraft General Declaration, as evidence of disinsection. A record of the disinsection shall be made in the aircraft's log.

b. The insecticide aerosol shall be sprayed in the aircraft for a minimum of 6 seconds for every 1,000 cubic feet of space, directing the nozzle of the dispenser at an angle of 45° towards the ceiling throughout.

c. The ventilation system must be closed during the spraying and for a period of not less than five minutes following spraying.

d. The flight deck shall be treated at a suitable time just before expected occupancy by the flight crew, the windows and door or curtains of this compartment being then closed and kept closed, except when the doors or curtains are opened momentarily to permit the passage of the crew members, until the 'blocks-away' treatment and the take-off of the aircraft are completed.

e. All other parts of the aircraft, accessible from within the aircraft, shall be sprayed after all cargo is loaded, the passengers and crew have embarked, and the doors have been secured. All possible spaces where insects can harbour inside the aircraft shall be treated (including any toilets, galleys, cupboards, chests, and compartments for clothes, luggage and freight). All foodstuffs and utensils inside the aircraft shall be covered and protected from contamination during spraying.

f. All parts of the aircraft accessible only from the outside, including the recesses provided for the landing-gear, shall be disinsected. The cargo compartments shall be treated immediately before the compartment doors are closed. The wheel-wells shall be disinsected at the last practicable moment before the engines are started in preparation for take-off.

g. The aerosol spraying shall be recorded in the aircraft's log. Copies of all aerosol

spraying records, including the aircraft's identification number, shall be provided to the Command Surgeon Air Command.

26. 'Top-of-descent' disinsection shall be done by the air crew under the direction of the aircraft commander as follows:

a. The insecticide to be used is 2% d-phenothrin, which is supplied in hand-operated aerosol cans. The aerosol dispensers shall be serially numbered and the serial numbers entered on the Health portion of the Aircraft General Declaration Form. The empty cans must be retained after use and, upon arrival at country of destination, will serve, together with the entries on Health part of the Aircraft General Declaration, as evidence of disinsection. A record of the disinsection shall be made in the aircraft's log and copies shall be provided to the Command Surgeon Air Command.

b. The insecticide aerosol shall be sprayed in the aircraft for a minimum of 6 seconds for every 1,000 cubic feet of space, directing the nozzle of the dispenser at an angle of 45° towards the ceiling throughout.

c. The ventilation system must be closed during the spraying and for a period of not less than five minutes following spraying.

d. Aerosol spraying will be limited to accessible areas within the aircraft, not including the flight deck. All possible harbours for insects inside the aircraft shall be treated (including any toilets, galleys, cupboards, chests, and compartments for clothes, luggage and freight). All foodstuffs and utensils inside the aircraft shall be covered and protected from contamination during spraying.

e. The aerosol spraying shall be recorded in the aircraft's log. Copies of all aerosol spraying records, including the aircraft's identification number, shall be provided to the Command Surgeon Air Command.

27. Residual spraying shall be carried out for the control of crawling insects in all fixed- and rotary-wing, transport aircraft that are being used in foreign countries for the transportation and delivery of food materials as follows:

a. Prior to leaving Canada, the aircraft commander shall ensure that residual spraying is done immediately following the thorough cleaning of the aircraft.

b. Mixing and spraying of insecticides will be done by the preventive medicine technician or a licensed, civilian pesticide applicator who is under the direction of the preventive medicine technician.

c. The insecticide to be used is bendiocarb, which is supplied as a wettable powder concentrate (i.e., Ficam Plus Synegized Pyrethrins Wettable Powder, a 29.45% bendiocarb/3.06% pyrethrins formulation). It is to be used in rotation with a second insecticide (Bugcon Super Space & Contact Residual Insecticide Solution, a 0.7% pyrethrins/4.0% piperonyl butoxide) to minimize the development of insecticide resistance. Both insecticides are for mixing with water and application using a hand-operated 1-, 2- or 3-gallon sprayer.

d. The insecticide shall be mixed according to Canadian container label directions and precautions. The person applying the residual spray shall wear coveralls, rubber

boots, neoprene gloves, vented goggles, and a respirator of the type listed in CFMO 36-03 while applying the insecticide inside the aircraft.

e. Following thorough cleaning of the aircraft (see para 12-15 above) by the air crew or maintenance personnel, the spray mixture shall be lightly applied to the point of run-off, on a monthly basis, to all accessible interior surfaces except the flight deck, any areas immediately adjacent to electronic equipment, windows, and seat cushions and backs. The preventive medicine technician shall be advised by air crew or maintenance staff of the precise locations of any sensitive electronic equipment.

f. The residual spraying shall be recorded in the aircraft's log. Copies of all residual spray records, including the aircraft's identification number, shall be provided to the Command Surgeon Air Command.

De-ratting Procedures for Aircraft

28. Generally, aircraft fumigation is aimed at serious infestations of insects or rodents sighted aboard aircraft. Routine infestations of insects are usually handled through the use of contact and residual spraying. With rodents, there are 3 options: trapping, baiting, or fumigating. However, because aircraft must be available to meet operational schedules, trapping and baiting are too inefficient. The only quick means of de-ratting an aircraft and preventing costly damage to aircraft components is to fumigate the aircraft as soon as possible.

29. The following 3-step procedure applies to any DND aircraft that is found to be infested with rodents:

a. Any aircraft within which a rodent has been sighted will immediately be grounded until such time as the aircraft has been inspected by maintenance personnel and known to be free of rodents.

b. The aircraft shall be fumigated with methyl bromide by trained and licensed preventive medicine technicians or fumigators. No other fumigant shall be allowed. The Surgeon General's Directorate of Health Promotion and Protection (DHPP) must be consulted prior to implementing this work because only DHPP has the responsibility to authorize an aircraft fumigation. Sticky, rodent traps shall be set up inside the aircraft, spaced every 2-3 metres along the walls, to trap any rodents that are disturbed by the gas and to minimize the chances of any rodents dying in inaccessible areas and later becoming an odour problem. The fumigation shall be recorded in the aircraft's log. Copies of all fumigation records, including the aircraft's identification number, shall be provided to the Command Surgeon Air Command.

c. The aircraft's wiring and cables shall be carefully inspected by maintenance personnel to ensure that none have been damaged by rodents.

30. Aircraft fumigation procedures take 2.5 to 5 hours, preferably including the following steps:

- After an aircraft is empty, cleaned, and parked well clear of buildings and other aircraft, the fumigation crew arrive. The technicians then set up their specialized fumigation equipment.

- The service technicians first perform a security check to make sure that there is no-one left on board. They place warning signs around the aircraft stating 'Keep away. Fumigation in progress'. They then place 5 kg cylinders of methyl bromide throughout the plane. Pure methyl bromide must be used; not a methyl bromide formulation with a chlorpicrin additive. The latter is essentially picric acid and it has a corrosion potential.

- Each pre-weighed cylinder of fumigant may be connected to its own small computer, which, in turn, may be connected by a network to the other computers (e.g., 6 sets per 747). Each cylinder is fitted with a 60 psi regulator and an atomizing jet that controls the gas's release and ensures that there are no free droplets of the fumigant.

- When the cylinders are set and ready to go, the technicians do a final check and close all but one of the aircraft's doors. As the technicians turn on each computer, a green light on top of the unit lights up. When all computers have a green light, the countdown starts. The technicians then disembark and seal the plane. After 10 minutes, the computers open the valves on the fumigation cylinders.

- The computers shut down the entire system after another 20 minutes when the tanks are empty. The plane is left sealed to give the fumigant time to do its job.

- After leaving the aircraft sealed for sufficient time (2 hours for rodents and 4 hours for cockroaches), the technicians, wearing self-contained breathing apparatus (SCBA), turn on a mobile air conditioning unit, open all of the doors and re-enter the plane. They then shut-down the computers and carry out their equipment.

- Gas checks are made to ensure the fumigant has cleared the aircraft, especially areas known to have low air movement. Air can be rammed in to the aircraft if necessary. It may take 30-45 minutes for all of the gas to clear all areas of a large aircraft, including foam seats and insulation batts. Once the gas level is below the acceptable threshold of 1-2 ppm, the fumigators will issue a clearance certificate and remove the warning signs.

Garbage Disposal Procedures

31. Aircraft cabins shall be routinely examined by air crew for any materials discarded by passengers, especially any materials that may harbour pests or diseases. In particular,air crew will watch for any 'empty' food containers, scraps of food (e.g., fruit, meat, cheese), live animals (e.g., snakes, birds, amphibians), seeds, and meat products. The careful removal and proper disposal of garbage is a vital component of plant and animal quarantine.

32. Air crew shall secure all such garbage in plastic bags for removal and disposal. Garbage shall not be removed from aircraft entering Canada unless it is first placed in disposable, closed containers.

33. All aircraft garbage entering Canada shall be disposed of in an incinerator or at a federally-approved landfill site as applicable with current federal regulations.

34. Toilet wastes shall be disposed of in the airport or base sewage system.

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DISCLAIMER

Trade names have been used solely for the purpose of providing information. Mention of a trade name does not constitute a guarantee or warranty of the product by the author or the Canadian Department of National Defence or an endorsement by either over other products not mentioned. Although specific pesticides have been mentioned, the reader should be aware that existing pesticide labels are regularly revised and that new products continually become available for use in pest management programs.

Because there are wide differences between pesticides and their formulations and because individuals may react differently to them, every pesticide must be handled with due care. Label instructions and other literature that accompany a product must be followed at all times. One must always read and follow the pesticide product label because it is the final legal authority as to its use and application.

Although special care has been taken in preparing this report, neither the author nor the Department of National Defence can be held responsible for any errors or omissions. No representation, guarantee, or warranty is made to the accuracy, reliability, or completeness of the information, specifications, procedures, methods, materials, or equipment in this report. Readers are cautioned to satisfy themselves as to the suitability of the material provided prior to its use and to follow label directions carefully.

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14. Abstract

Aircraft disinsection is an important tool in preventing the introduction of unwanted pests into a country when an aircraft is returning to its home base. To prevent risks to air crew health, aircraft safety, and industry, Canada's Department of National Defence (DND) has reviewed the importance of aircraft disinsection and the potential problems associated with execution. Over the past two decades, various directives for air crew maintenance personnel, and preventive medicine technicians have been developed and updated periodically. This aircraft disinsection review is part of the latest effort to revise DND's administrative orders on aircraft disinsection.

Existing Canadian and foreign legislation, regulations, and recommendations dealing with aircraft disinsection were reviewed. This review also summarises the information that was gathered from various officials involved in the regulation of introduced pests, pesticide registration, and safe pesticide use. Aircraft disinsection technology has evolved over the years since its inception. Practical, up-to-date information on current technologies was gathered, through numerous meetings and correspondence, from researchers, private companies involved in aircraft disinsection, air force personnel, and representatives of civilian air carriers who are active worldwide. The end-result was the development of a current, standard operating procedure for disinsection of Canadian Air Force aircraft in the form of an Air Command Administrative Order. It may serve as a model for the Air Forces and air carriers of other NATO countries.

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